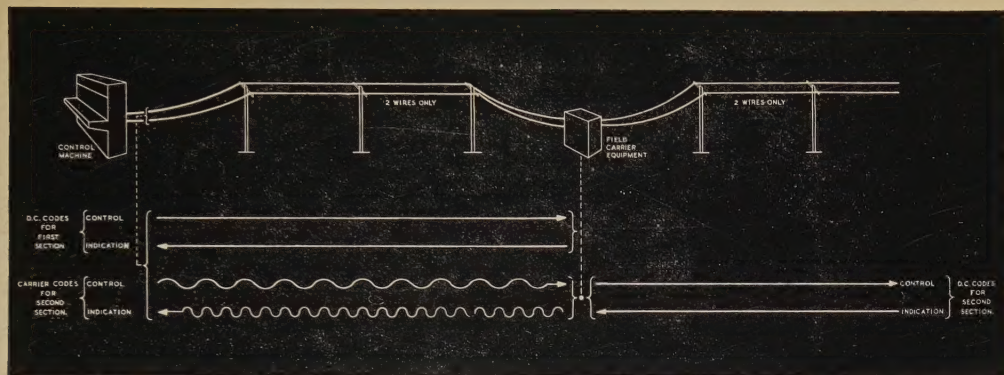


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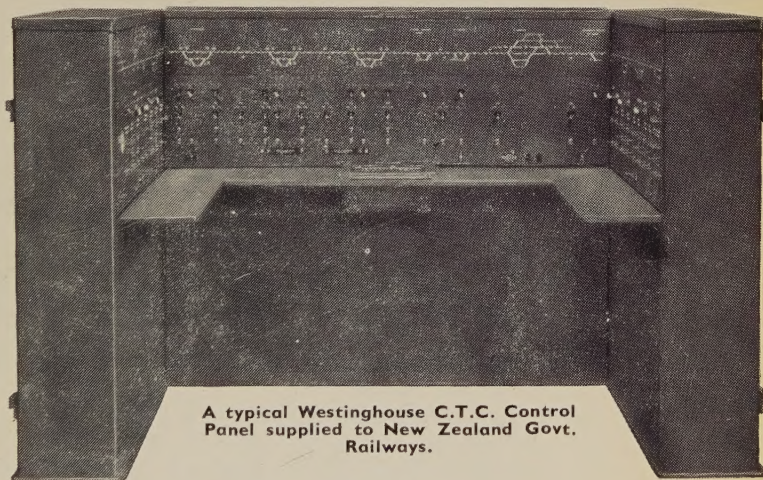


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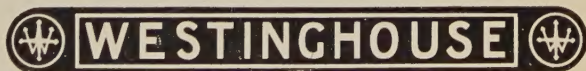
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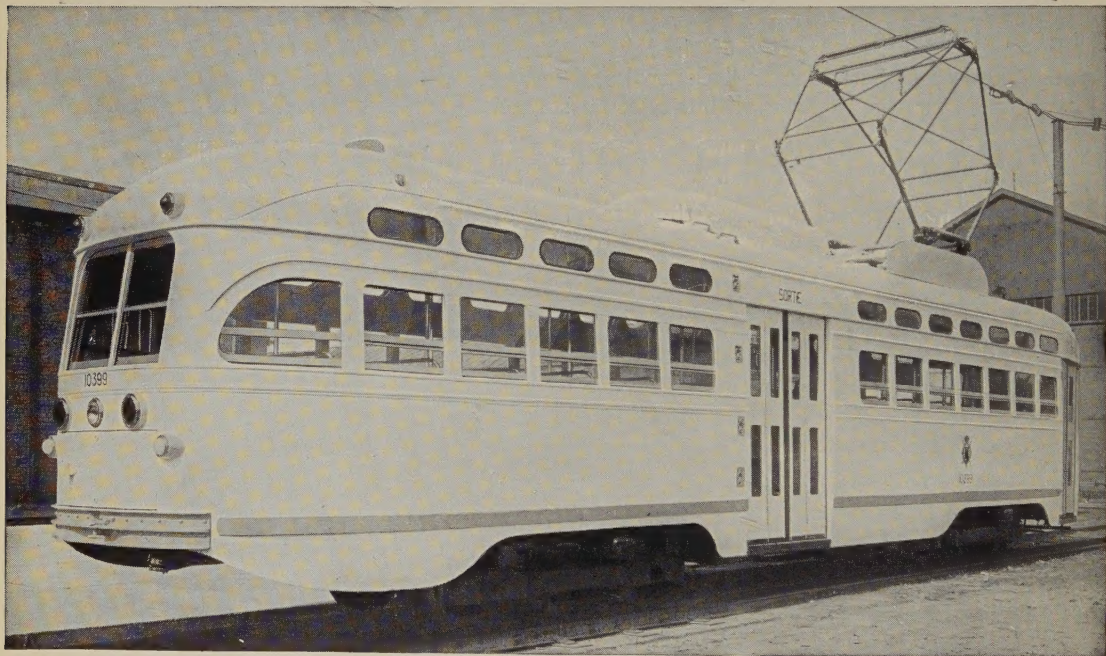
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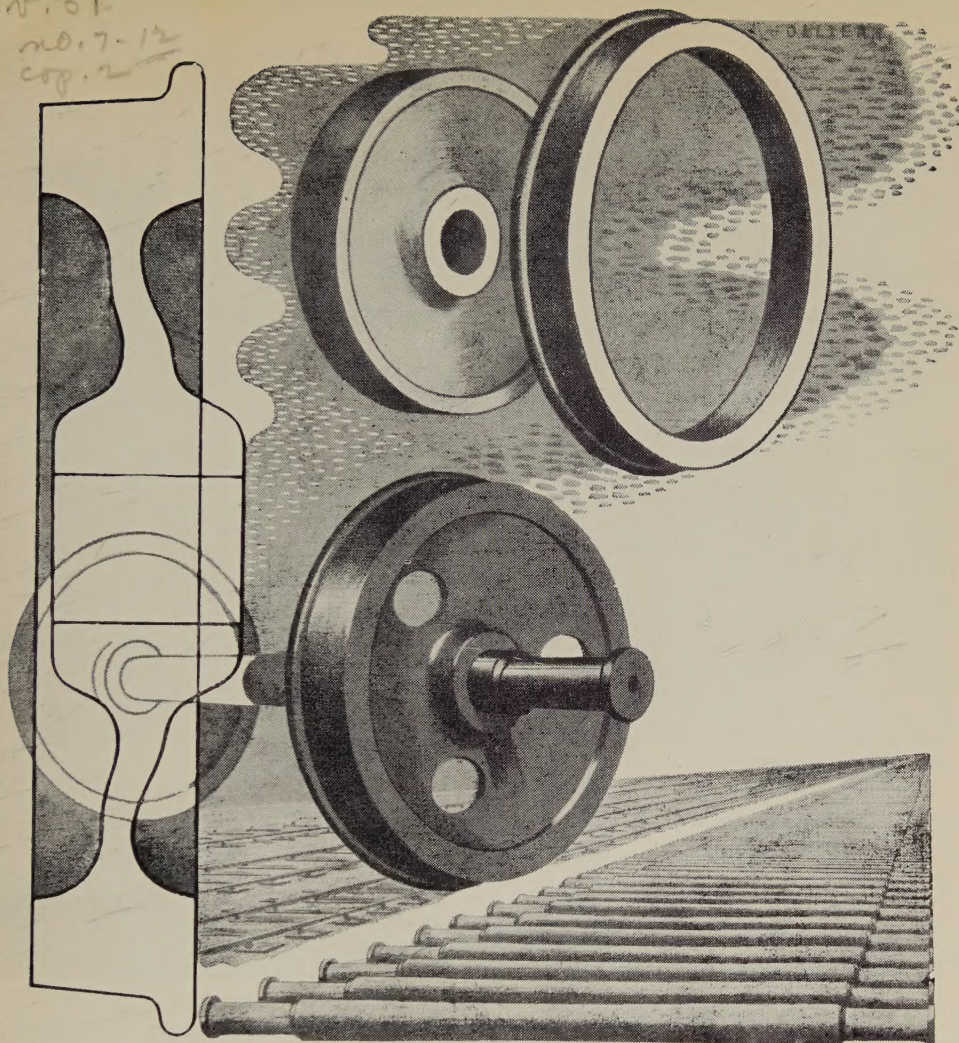


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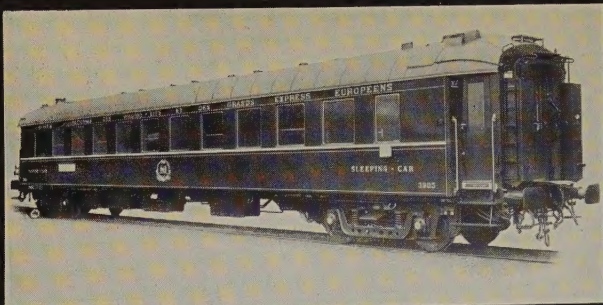
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'The Times' photograph by courtesy of British Railways

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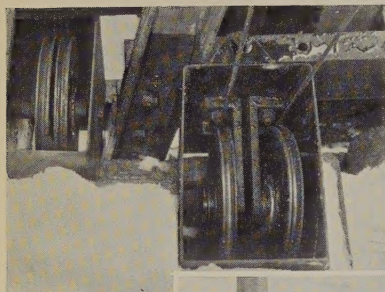
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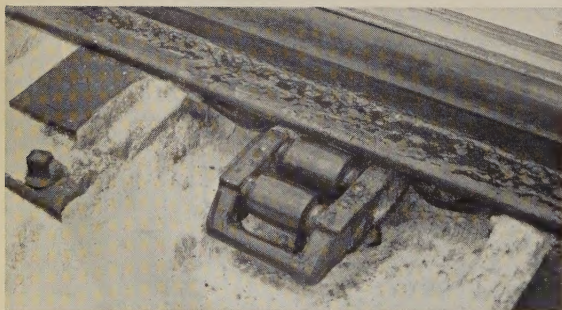
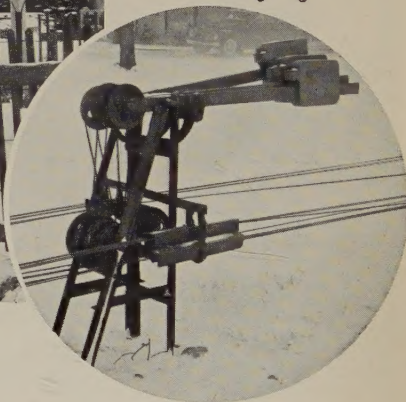
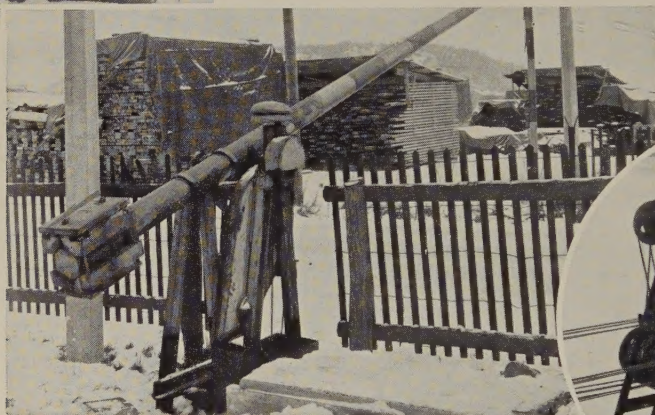
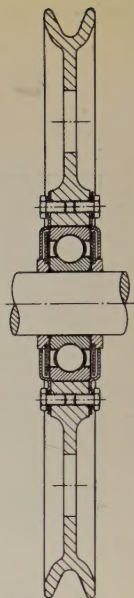
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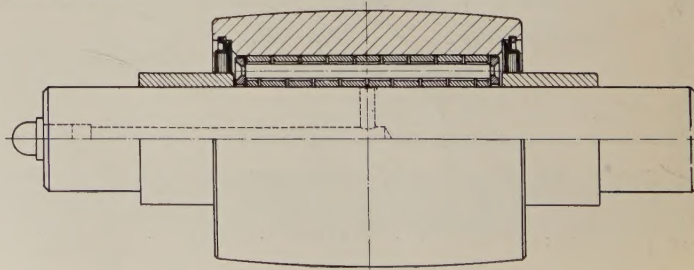
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BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS

ASSOCIATION

(ENGLISH EDITION)

[656 .25 (42)]

Signalling developments on British Railways,

by L. W. HATLEY,

(British Transport Commission, British Railways).

The developments in British Railways signalling practice have proceeded generally along well defined and conservative lines. In suggesting that conservatism has played an important part in this it is not implied that due regard has not been paid to developments elsewhere but that the channels of development have been appropriate to the Operating and physical conditions of British Railways. It is true to say that Great Britain has been the pioneer country in the construction and operation of railways and as a natural consequence it has developed a system of signalling commensurate with the growth and needs of the traffic to be dealt with.

It is not necessary to burden the reader with an historical survey of the developments which have taken place and it is sufficient to note that the most important single factor was the change from « Time Interval » to « Space Interval » working. The reasons for this change were two-fold, the urge for greater safety and the need to increase line capacity.

The block system.

In the early days of the nineteenth century there was considerable objection

to the construction of railways and fears were entertained by many people that such a form of transport could only lead to disasters. With the primitive methods in use in those pioneer days a number of accidents did occur, which resulted in public agitation culminating in a certain amount of legislation for the control of railways. Safety loomed large in these controls and an Act of 1889 imposed upon the then several independent railway companies the necessity for instituting on all passenger lines a system of Block Telegraph Working. Prior to the passing of this Act, however, many of the railways had already provided this equipment for the safety and better regulation of their traffic.

The « Space Interval » method so engendered has remained the basic principle in British Railways signalling methods. The Block Sections in those early days were usually governed by the situation of stations, yards, or junctions, resulting in a certain irregularity in the length of the sections, but the situation was fairly well met.

The Block system on British Railways has always been of the « Closed » type,

Semaphore signalling associated with block working.

The introduction of semaphore signals had developed along with the Block system and a fairly general pattern evolved. This pattern consisted of a Distant (or Warning) signal, giving advance indication of the need to stop, a Home signal protecting the points worked from the Block post and a Starting signal to give permission to enter the Block section ahead.

With the growth of traffic (and it is important to remember that this was of varying types, namely, long distance fast moving passenger trains, suburban passenger trains, mixed freight trains, and heavy mineral trains) these inequalities in the Block sections became more of an impediment to free movement. To a considerable extent the irregularities were ironed out by the provision of additional Stop signals, such as Advanced Starting signals to get a train further on its journey when Block acceptance was refused, and Outer Home signals to admit of acceptance whilst junction movements were taking place or local shunting was performed at a Block post. Further sub-division of the Block Section has been accomplished by means of Intermediate Block Section signals.

Modern controls have been associated with the Block system, so as to prevent the clearing of the Starting signal before the train has been accepted by the box ahead, and to ensure replacement of signals after a train has passed by making it impossible to accept a following train until the Distant and Home signals have been replaced to Caution and Danger respectively.

A further control, known as the Welwyn Control, is now being provided, which, subject to the Signaller seeing the tail lamp, ensures that a train has passed through the Block Section before a following train can be accepted.

This general pattern of semaphore signalling, which has remained constant in British Railways, has been the background against which the modern types of signalling have been provided. The essential feature is the Distant signal, which has to be sited in such a position as to enable a train of any description to Stop at the next Stop signal ahead if it should be at Danger and, therefore, has its effect upon the headway. On the other hand this signal makes an important contribution to line capacity as when it is cleared it gives the Driver complete confidence to proceed throughout the inter-locking ahead and into the next Block Section. The Distant signal is distinguished from a Stop signal by means of a fish tail arm and a Yellow light, in place of the Red light in a Stop signal.

With the introduction of electricity to railway signalling, layouts became much more extended, because of the ability to operate points at greater distance (it is pertinent to remark that the limit for mechanical operation points in Great Britain is 350 yards), so that additional Distant signals for running purposes became a feature. This in effect meant that when the Distant for an interlocking was at Caution and the line subsequently cleared the Driver was given an opportunity of regaining his speed by a further Distant signal ahead.

Colour light signalling.

In closely signalled territory it was common practice for the Distant signal of the forward box to be fixed under the Starting signal of the rear box, thus in effect creating a three aspect signal. With the introduction of colour light signalling (a further advantage derived from the use of electric power) it was not unnatural to combine these three aspects in one signal, thus creating the now familiar Red, Yellow, Green signal, with the respective meanings Stop, Proceed at Caution and Proceed at unrestricted speed.

Braking distance between the Yellow and Red became insufficient in closely signalled territory where a close headway of trains was required, and this condition was met by the introduction of the fourth aspect, namely, Double Yellow so that the sequence of aspect for a Driver who was required to Stop would be, Double Yellow, Single Yellow, and Red. In effect each multi-aspect signal is a Stop and a Distant signal but the aspects in this form give greater information to the Driver than is obtained from semaphore signalling for the reason that in the three aspect signals a Green signal indicates that at least two signal sections ahead are Clear and in a four aspect sequence the Green indicates that at least three signal sections are Clear. This gives Drivers much greater confidence, particularly where electric traction is involved.

The development in respect of Colour light signalling has been fairly extensive, but in the main has been limited to the intensively worked suburban lines, im-

portant stretches of main lines and large inter-lockings. The reason for the introduction of colour light signals in the latter instance is because of the large areas controlled by power signalling and the obvious advantage of providing light signals where electric operation is necessary.

Great Britain is a country very much subject to fog necessitating the employment of Fogsignalmen. It has been found that with the higher penetrating power of light signals these men are not required, and consequently upon important main lines it has become the practice to provide colour light signals in place of the semaphore Distant signals, making both for greater safety and better working during fog. These colour light Distant signals take the form of two aspect Yellow/Green signals, unless they are associated with a Stop signal when the third aspect, namely, Red, is introduced. On lines where high speed trains are run, however, it has been the practice to retain the semaphore Distant signal, thus providing braking distance for the slower speed trains and to provide an Outer colour light Distant signal to give braking for the high speed trains. In these cases the Outer Distant shows Double Yellow or Green, and as the Double Yellow will lead up to the semaphore Distant with its Yellow light the normal sequence of colour light aspects, namely Double Yellow, Single Yellow and Red is maintained.

The aim of British Railways has been to produce a simple system of aspects and to preserve a consistency between semaphore signalling and colour light signalling, thus avoiding too many com-

plications to a Driver when passing from one form of signalling to the other. As a consequence of this it has not been the practice to provide, by means of aspects, any indication of the speed to be travelled, and with the exception of one experimental installation there is no form of speed signalling in existence. The natural result is that it is an essential requirement that Drivers shall have a full understanding of the routes over which they have to travel, not only of the signalling but of the gradients, speed restrictions, and other physical characteristics. No difficulty has been experienced in this respect but Drivers are required to sign that they are fully competent in this respect before being allowed to take charge of a locomotive on a particular route.

Junction signals.

In semaphore signalling indication of direction at a junction is usually given by means of laterally spaced signals, the signals for the higher speed route being spaced at a higher elevation than the signals for the other route. In colour light signalling, however, this lateral spacing has largely been superseded by a form of junction indicator. This consists of a row of white lights, which show by their degree of divergency from the vertical, the direction of route to be travelled. The following photograph shows colour light signals at a scissors crossing with junction indicators applying through the connections from each line. No junction indication is given for the straight route and thus a diversion from the straight route, normally necessitating

a reduction in speed, is given greater prominence.

At places where slow speeds obtain, indication of diversion is given by means of a route indicator, more usually of the « Music Hall » type which shows by an arrangement of lights a letter or numeral indication the line on to which the Driver is to proceed. With both junction indicators and route indicators the main signal applies, thus avoiding additional separate signals, which is an important consideration with colour light signals when the maximum benefit is



Junction indicators at scissors crossings.

obtained by proper focussing to the Driver's eye.

In an article of this nature it is not possible to enumerate all the factors associated with the colour light signalling

in operation on British Railways, largely in connection with the intensive London suburban services, although there are some extensive installations on some of the main trunk lines. These have



Euston power signalling frame.

system on British Railways but the foregoing will serve to show the main characteristics.

Automatic block signals.

There are a fairly large number of Automatic Block signalling installations

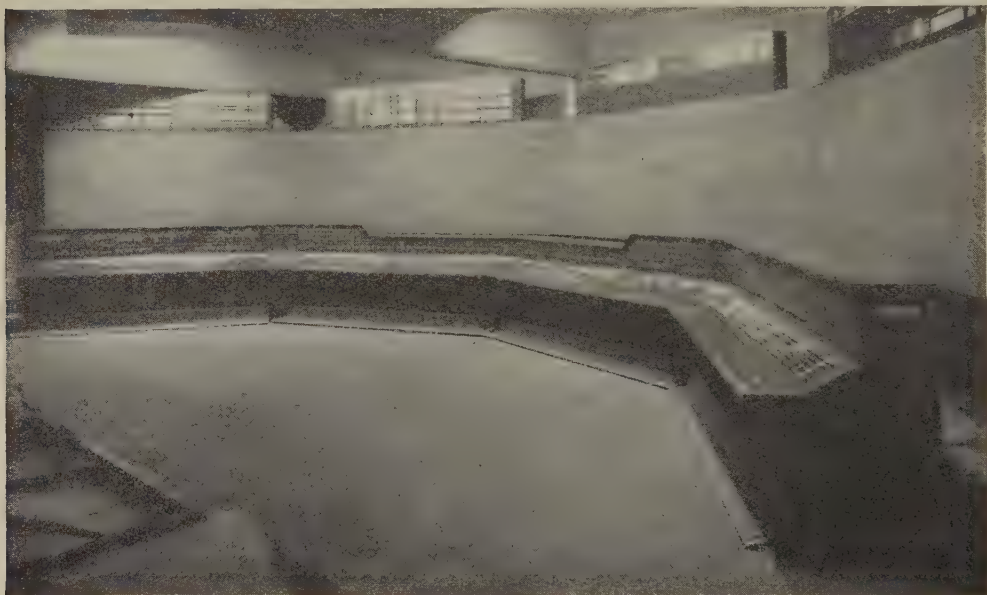
generally been provided for one of two reasons, namely the need for a closer headway because of the growth of traffic, or to enable economy to be effected by the closing of intermediate block posts.

These Automatic Block installations are the only exceptions to the otherwise general « Closed » Block principle.

Power signalling.

Power operated points have become an increasing factor in British Railways signalling, starting firstly with the remote control points from an already existing mechanical box and going on towards the complete power operation of all points and signals covering a large area.

elsewhere. The reason for this is because a system of signalling which was adequate to the traffic needs could scarcely be abandoned for a C.T.C. installation for which there could be no financial justification. On the other hand there has been considerable development in the combination of signal



York relay interlocking panel.

In this respect Great Britain differs little from other countries, but it is important to note that with the very comprehensive system of signalling and traffic control gradually developed from the inception of the railways, little opportunity was available for large scale developments of such methods as Centralised Traffic Control as are experienced in the United States of America and to a less extent

boxes at large centres into one central cabin, the most noteworthy of these being the installation at York where approximately 8 route miles of line are controlled from one central box.

With the introduction of power signalling the miniature lever frame firstly found favour, and is in use in various forms and degrees of modernity at many places in the country. In later years,

however, the panel system has commended itself in many quarters and there are now a number of large installations controlled by these means. At the outset the fixing of the control switches on the actual illuminated diagram was introduced, but with the growth of these installations it was found that at the larger places it would be necessary to remove the controlling switches from the diagram because of there being insufficient room to properly accommodate them and, therefore, they were placed in banks on a console in front of the diagram.

These control panels are of the route relay inter-locking type, with one exception, namely, Doncaster, where it is of the sequence switch type, a form of control used in automatic telephone working.

At this stage of development a final decision has not been reached as to the efficiency of the panel system over the miniature lever frame, or vice versa, and the issue will require to be left for further experience to be obtained of the panel system, although it can be said that the results to date are encouraging. Illustrations are shown of the most recent miniature lever frame at Euston and the relay inter-locking panel at York.

Automatic train control.

In the development of British Railways signalling the opportunity has been taken of providing modern Block controls in conjunction with the signalling, so as to minimize errors on the part of the Signaller in the Block signalling of trains or in irregularly clearing signals. Further,

track circuiting has been widely used. Insofar as the Drivers are concerned, however, the main improvements have been in the better sighting of semaphore signals and also in the provision of colour light signals. On the former Great Western Railway, a system of A.T.C., applicable to the Distant signal only, was developed in the early part of the century and by 1938 it had been installed on the whole of the main lines of that railway. This system was a contact one, consisting of a ramp fixed in the centre of the 4' way and about 40' long, which made contact with a shoe fixed on the locomotive. When the Distant signal was at Caution no energy was applied to the ramp and the lifting of the shoe by contact with the ramp caused the brakes to be applied on the locomotive and a hooter to sound in the cab. A cancelling handle was provided to enable the Driver to cancel the brake application and the hooter and he then took over the control of the train. When the Distant signal was at « Clear » an electric current was applied to the ramp, which when contacted by the shoe on the locomotive, caused a bell to ring in the cab but with no action upon the brake equipment.

Many systems of A.T.C. have been tried out by the various constituent companies of British Railways over a long period of years mostly all of which have been of the contact type, but the Great Western system was the only one of this nature which was fully developed. A non-contact magnetic system was, however, developed by the former L.M.S. railway and put into full service on the London to Southend line of that railway.

It is important to note that there has been no legislative requirement in respect of the provision of Automatic Train Control and there can be no doubt that the low accident ratio, in conjunction with the development of colour light signalling, has led to a very slow development of this system of control upon British Railways. However, with the inception of the Railway Executive on the nationalisation of railways in 1948, that Body, in conjunction with the British Transport Commission immediately accepted in principle the desirability of providing an Automatic Train Control system so as to afford the final link in the chain between the Signaller and the Driver. The former Great Western system, which had proved entirely satisfactory for the conditions of that railway, had certain limitations mainly in respect of electric traction, because of the danger of the ramp fouling the motorcases of electric trains. It was, therefore, necessary to consider a form of Automatic Train Control which could be of universal use throughout the country and to take note of the fact that electric traction would undoubtedly increase. The magnetic inductive system on the Southend line was an obvious alternative but it suffered from the disability of not giving a distinct audible warning for the Caution indication, as in the case of the G.W. system. Therefore, a combination of these two systems was developed, but complications ensued because of the differing make-up of locomotives of the former companies of which there are some 19 000 in operation on British Railways. It was, therefore, necessary to entirely re-design the equipment and experiments

were undertaken to produce a unit which would be suitable for all steam locomotives and for adaptation to electric stock. Steam locomotives on British Railways are provided with the vacuum brake, whereas electric trains have the Westinghouse brake, and, therefore, the equipment must be designed to work with either system of power brakes.

Considerable development has taken place and a large scale trial is now in operation on the East Coast Main line between New Barnet and Huntingdon, where 53 signals have been equipped and 54 locomotives fitted. These trials show very promising results and it can be stated that the general principles of the equipment are satisfactory. There appears to be little doubt that as a result of the trials a completely satisfactory design will be produced for manufacture on a full scale production basis. This British Railways system, in common with that of the Great Western system, is limited to the Distant signal or its colour light equivalent, and it has not been thought necessary to go to the further additional expense and complication of providing for a positive Stop at a Danger signal, a difficult matter because of the differing types of trains travelling at widely different speeds. The signalling of the London Transport Executive is, however, an exception to this because their lines are fully equipped with a Train Stop apparatus, which can be regarded as an essential requirement, having regard to the fact that such a large amount of the railway is tunnels and that the signalling headway is as close as anywhere in the world.

Progress and tendencies in railway signalling in the United States of America,

by A. L. ESSMAN

Chief Signal Engineer.

Chicago, Burlington & Quincy Railroad Company. The Colorado and Southern Railway Company and the Ft. Worth & Denver Railway Company, U. S. A.

Technical developments have quite naturally been important in progress of American Railway Signalling during the past 25 years but, in the opinion of many observers, the greatest single factor has been a growing awareness on the part of railway officials that signal systems are operating tools as well as safety devices. Signal engineers have become recognized as operating officers and are no longer regarded merely as technicians skilled in the art of applying and maintaining electrical devices. The modern signal installation involves careful study of track arrangements, train movements and operating methods.

From the development of the automatic block system, which provided maximum protection at minimum operating cost, to the development of centralized traffic control, American signal systems have been designed as facilities for increasing track capacity, safely and economically. They have provided facilities for more efficient use of tracks, motive power and cars and have thereby held the investment requirements for roadway and equipment to a minimum. They have obviously made substantial savings in current operating expenses

through requiring a much smaller force for directing and protecting train movements and through elimination of train delays which directly affect costs.

There have been some outstanding railway signal developments in recent years, but none have captured the interest of railway operating officers, executives and even the general public to the same extent as has the centralized traffic control system and the form of operation it provides. This system combines the fundamentals of the American automatic blocking systems with the European systems for authorizing train movements by signal indications. It combines automatic block signalling, interlocking and a train dispatching system into an integrated operating tool for safely and efficiently working long or short sections of railway.

Second only to C.T.C. is a significant current interest in car retarder installations. These systems perform a very important function as they provide for mechanized sorting of cars at considerable saving in cost, as well as expediting freight traffic through classification yards. One element in the current wave of interest in classification yard is

the growing need for elimination of yard delays, another factor has been the development of new features for car retarder systems such as automatic switching and automatic retarder action for speed control. There has also been renewed interest in cab signals and automatic train control devices for application to ultra high speed lines.

Construction activity.

According to statistics compiled by *Railway Age* and its companion publications, activity involving installation of new signalling in the United States and Canada during 1952 was as follows :

	<i>Miles Road</i>	<i>Miles Track</i>
1. Automatic Block	1 114.3	1 332.9
2. Centralized Traffic Control.	1 541.9	1 689.5
	<i>New Plant</i>	<i>Rebuilt Plant</i>
3. Interlocking :		
(a) Number of home signals	480	324
(b) Number of switches.	364	184
4. Interlocking — Automatic :		
(a) Number of Plants		28
(b) Number of signals		133
5. Grade Crossing Protection :		
(a) Number of crossings		1 435
6. Cab Signals and Train Control :		
(a) Miles of track		1 409
(b) Locomotives equipped		946

Construction during 1952 was at a high volume, somewhat more than 1951

but about the average for years since World War II. It is difficult to find a completely accurate index of signal construction since there are so many different types of functions to consider. In general, however, many of our profession are of the opinion that the limiting factor to signal construction is availability of personnel at both the engineering and installation level.

In order to keep pace with the demand for more signal installation work, many railroads have resorted to the purchase of factory wired instrument housing. Others have set up central shops where wiring, particularly for large projects, can be performed under more favorable conditions than in the field. Thus we are able to install large mileages of signalling with comparatively small field forces.

An interesting trend in signal construction is indicated by the index compiled by *Railway Age* as to activity. The index they use is generally based on the number of new signal units placed in service during each year. Some recent changes in the compilations have brought about conditions which might slightly alter the relationships, but in an analysis made several years ago the following conclusions were derived from the data.

<i>Period</i>	<i>Per Cent of Total Signal Construction</i>				
	<i>Auto Block</i>	<i>C.T.C.</i>	<i>Inter locking</i>	<i>Highway crossing Signals</i>	<i>Misc.</i>
1. — 4 Prewar Years. (1938-1941) . . .	17.2	7.0	23.0	41.8	10.1
2. — 4 War Years, (1942-1945)	21.7	28.3	22.5	10.8	16.7
3. — 4 Postwar Years, (1947-1950) . . .	15.0	23.9	14.6	31.5	14.9

From the above table it will be noted that a not inconsiderable amount of railway signalling activity involves the automatic protection of highway-railway crossings at grade. Usually this work takes precedence over construction activities involving operating facilities primarily designed to produce monetary savings in train handling, because of the greater proximity to the public interest.

I will not endeavour to cover descriptions of specific technical advances in signalling. Most of these have been presented to you by the various commercial interests involved and by descriptions in the technical press. Because the Centralized Traffic Control system combines protection and direction of traffic in one « package » and because I believe it is not only the most outstanding system of signalling today, but the fundamental upon which railway signal activity, for many years to come will be based, I would like to say a little more about it.

History of centralized traffic control.

Centralized Traffic Control as we know it today was not an accidental development. It came about after the thinking of the signal engineering profession had already been firmly established in the general premise that, somehow or other a practical and economical method of running trains on single track by signal indications must be developed. Such systems were first offered and installed in the late 20's and were being installed at a gratifying rate, for a new development, until the depression of the '30's very materially slowed

down all railroad construction. By 1939, almost twelve years after C.T.C. was first offered, there were only about 2 000 track-miles equipped.

Today we have about 18 000 track-miles of C.T.C. signalling in the United States alone. The total in the Western Hemisphere is more than 19 000 track-miles. Installations are in service in Canada, Mexico and Brazil and are being contemplated in several other Western Hemisphere countries. The Chicago Burlington and Quincy Railroad, with which I am associated, has nearly 1 500 track-miles governed by C.T.C. Two other railroads, the Atchison Topeka and Santa Fe and the Seaboard Air Line, have slightly more than 1 500 track-miles each. In addition to these three railroads, there are half a dozen others having more than 1 000 track-miles of this modern signalling.

Centralized traffic control was installed at the rate of 1 248 track-miles per year during the four war years 1942 through 1945, with a peak of 1 733 track-miles in 1945. During this period signal projects constituted a much higher percentage of total project authorizations than they normally do, because they provided a means for increasing track capacity quickly and with minimum quantities of critical material and, in many cases, constituted the only way in which increased capacity could be secured within material limitations. It is estimated that signal construction authorizations in a typical war year were being made at a rate of nearly 20 % of total way and structures authorization, instead of at about half that rate, which prevailed in 1950.

Installations of C. T. C. have been made at the rate of about 1 500 track-miles per year beginning in 1947, when the peak of 1 845 track-miles was equipped. This continued demand for C.T.C. following the heavy demand during the war years, is the best possible evidence of acceptance of the system, particularly since it is being adapted to lines of moderate and even light traffic as well as to capacity traffic lines.

C.T.C. has been installed very extensively on single track lines. It has been installed on all the single track portions of the joint C. B. & Q., D. & R. G. W., Western Pacific route between Chicago and the West Coast; also on all single track portions of the joint C. & N. W.-U. P. route to Los Angeles from Chicago. Other extensive installations cover the single track Seaboard Air Lines, routes to both coasts of Florida from the railroads' northern extremity.

We are beginning to see the possibilities of C.T.C. on heavy traffic double track lines more clearly than in the past, although there have been a number of installations in service for many years. One factor which promises to expedite this trend is the desire of railroads to use mechanized track equipment. Effective use of this highly efficient mechanical track maintenance equipment requires release of a track for maintenance purposes ordinarily for a longer period than it could be spared from operation by heavy traffic. C. T. C. facilities will make it possible to route trains around these obstructions. Double track C.T.C. in the vicinity of large terminals has proven effective in providing capacity to handle simultaneous direc-

tional peaks of freight and passenger movement in morning and evening rush hours.

Operating savings with C.T.C.

The operating savings from a centralized traffic control installation are usually sufficient to offset the initial cost in three to five years, and in some cases in a shorter period of time, on lines of moderate to heavy traffic density, where the line is already equipped with automatic block signals.

On lines programmed for automatic block signalling as a matter of protecting traffic, it is often possible to demonstrate an economic advantage for the additional cost of C.T.C., even where there is comparatively light traffic. Frequently the spread between the first cost of C.T.C. and a conventional automatic block system is not great because it is possible to design the layout with fewer sidings than would be required under automatic blocking, and the savings secured are sufficient to produce a high rate of savings on the additional cost. A number of installations have been authorized on this basis, and more are in prospect especially where railroads are desirous of operating trains at higher speed than that permissible on non-signalled lines.

Signal improvements associated with track modernization.

Study of a line for application of C.T.C. is usually associated with a complete review of the track layout. On a signal track line, the questions of num-

ber, location, and length of sidings are reviewed, and the resultant track and signal layout is one that can be expected to meet operating requirements.

Installations of C.T.C. on heavy-traffic single-track lines have postponed or avoided the need for installation of second main tracks. Many of the earlier C.T.C. installations and those installed during the war years provided such facilities.

On lighter-traffic lines C.T.C. could not be justified unless the first cost was reduced, and the most effective means of achieving this reduction lay in streamlining the track layout. Resistance on the part of operating officers to reduction of the number of sidings was evident in the early days of C.T.C., but, since actual installations have demonstrated the practicality of securing better operation with fewer sidings, full co-operation is the rule rather than the exception.

Appreciation of the capabilities of C.T.C. as a means of justifying simplified track layouts has extended beyond the point of removing sidings to the point where substantial segments of second main track have been removed because the first main track could be improved by C.T.C. to take care of a heavier volume. Consideration is currently being given to much more intensive projects for removal of the second main track and installation of C.T.C. on the remaining track. I am confident that this will result in an important source of C.T.C. business in the not too far distant future.

Although there have been some cases where second main track removal has

been accomplished without installation of C.T.C. on the remaining track, the availability of this type of signalling to bolster capacity if conditions required has probably influenced decision to make the retirement of track.

It is estimated that C.T.C. installations have been responsible, directly or indirectly, for the removal of at least 500 miles of second and third main track because of increased capacity secured or capable of being secured on remaining tracks.

Actively considered projects— second track removal.

Many projects of second track removal are under consideration at the present time. All of the projects are beyond the theoretical discussion stage and have excellent chances of being authorized. They are not confined to any one section of the country. Transportation studies of the economics of these projects have shown that the proposed C.T.C. single track would handle the present and anticipated traffic volume without appreciable deterioration in train performance.

Most of the projects under consideration would involve a net cost less than that of other work that would have to be undertaken in the near future if the second track was retained, because of imminent rail renewal programs, modernization of old signalling, and the like. Value of recovered materials even at minimum appraisals is high at this time, and a favourable situation for write-off of abandoned property exists.

Conclusion.

I believe the outlook for railway signalling is good from both the short-range and the long-range viewpoint, because railroad operating officers and financial interests are far more « signal-minded » than they have ever been. Signalling has been accepted as a means for improving train handling far beyond its basic function of providing safety.

The credit for establishment of the vastly greater interest in signalling on the part of railroad management can largely be claimed by the centralized traffic control system, one installation of which does much to create demand for another. C.T.C. has contributed to more efficient railroading, even on portions of the road not equipped with the system, because it has caused consideration to be given to

the combination of tracks, signals, and operation as an inseparable factor in good train handling. The horizons for its application have widened in one direction by the fact that it can be adapted to comparatively light traffic lines. They have widened in the direction of application to heavier traffic lines also, as is evidenced by consideration of C.T.C. as a means of making possible reduction in the number of main tracks, or in increasing effectiveness of double track operation on extremely heavy traffic lines.

Much of American railway signal progress has been associated directly or indirectly with the C.T.C. system and the tendency is toward greater and wider application of this extremely effective operating tool.

Safety of structures and control of the quality of the materials supplied for the purpose,

by Marcel PROT,

Ingénieur en Chef des Ponts & Chaussées de France, Docteur ès Sciences - Docteur ès Lettres.

The idea of safety.

To a railway engineer, the notion of safety naturally suggests an accident and is generally expressed by a certain number of killed or wounded. To the engineer who constructs a bridge or a dam, the degree of safety is expressed by a coefficient of safety and denotes an almost absolute certainty that no accident will take place.

Whence arises this apparent contradiction and how is it that the same word has two meanings that are so contradictory ?

In truth, the notion of safety, in spite of a deceptive simplicity due to its familiar character, is really a rather subtle term, difficult to apprehend fully in conjunction with the various aspects that it may present.

The feeling of security is due, essentially, to confidence in the future, i. e. to a favourable forecast, while as regards insecurity, this corresponds to the sense of a risk, more or less precise or uncertain, according to circumstances. There is no call for a very far reaching psychological analysis, in order to separate the

character common to all the aspects of this many sided notion, it is the idea of a probability concerning certain future phenomena which, according to circumstances, may be favourable or unfavourable. The safety and the risk are not questions of all or nothing, but essentially questions of degree and of comparison.

Speaking very generally, insecurity is the probability of an accident, of the ruin of the work, in any case tragic, unfortunate or simply annoying, that one fears for some reason and which one tries to avoid; insecurity still more exactly stated, is that one's attention is drawn to every risk of this kind, even if small. On the other hand, security is the fact that attention is drawn to the complementary probability, i. e. that the probability of the feared accident will not take place or the fact that this probability is relatively feeble or that it has diminished. If the risk, even if only slight, of the accident increases, insecurity is increased, security is diminished.

Any prognostication is made in the light of knowledge of what has occurred in the past and of a sort of prolongation

by extrapolation of this fact directed towards the future. If we neglect intuition and faith (belief), forms that are worn out, misty, sentimental forecasts and instead concentrate our attention on rational, methodical objectives, which alone, should allow the engineer to make forecasts in the exercise of his profession and thereby enhance security in the field which is entrusted to him, we find in effect an attentive observance of a certain number of facts and the calculation of certain frequencies which it is admitted, will reproduce themselves in the future, all things in other respects being equal, and of which one can make a probability.

A probability is the anticipation of a frequency.

If from an urn containing white and black balls I have taken N balls of which P have been white and Q have been black ($P + Q = N$), the frequency of the draws made is :

$$p = \frac{P}{N}$$

for the white balls and

$$q = \frac{Q}{N} = 1 - p$$

for the black balls.

If I have to make a fresh draw, I shall say that the probability of drawing a white ball is p , i. e. I shall bet on the regularity of the phenomenon already observed and on the fact that I shall continue to see in the future what I have already seen in the past. What more

and better could I do, if I have no other indication ⁽¹⁾ ?

This scheme (diagram) is one of the simplest known; it can be complicated to an infinite extent by increasing the number of colours of the balls, the number of urns and the different methods of drawing lots; the psychological operation remains essentially always the same.

The problem of estimation.

The foregoing diagram, simplified to an extreme degree, only provides, according to all evidence, a first approximation, entirely inaccurate and practically useless in certain cases.

If for example, we have made only one drawing (of lots) and have drawn a white ball, the argument suggested by our arrangement would tend to support the certainty of the outcome, at the next drawing of a white ball when the urn might definitely only hold black balls, apart from the white ball which was obtained at the first drawing.

If in a general way, we have only made a few draws, if, in other words, we have only made a small number of observations, we could always calculate the frequency of the observed phenomena,

(1) The reader will find various developments of these psychological opinions, on the one hand, in our book:

Marcel PROT: « Langage et logique ». — I vol. 121 p. (Hermann, 6, rue de la Sorbonne, Paris, VI^e), 1949, and on the other hand in an article published in the *Annales des Travaux Publics de Belgique*, for August 1952, entitled « La Thèse probabiliste de la Sécurité ».

but we cannot foresee a repetition of this phenomenon in the future, except with a very dubious probability, very uncertain; this probability will be at most indicative and the most elementary prudence will advise us to employ a margin for the uncertainty, all the more so as the draws have been fewer.

We would, on the other hand, look for a very decided probability, if we had made a very large number of draws and we shall have all the greater chance of again finding in our draws in the future, a frequency of appearance of white balls equal to their frequency in the past, since the frequency was calculated with a much larger number of experiments.

The problem of estimation consists, given a certain number of observations, taken on a « sample population » selected from a much larger population known as the « mother population », in calculating which are the forecasts which can be reasonably imagined in respect to this « mother population » and to what degree one may expect to see the observations made in the sequence of the mother population differ from the observations made on the sample.

The problem is one of considerable practical importance, all the more so since it is very little known to engineers and is very critical.

It is important to understand that the estimate is always more or less uncertain: when I have drawn from the urn a certain number of balls, all white, it is in fact not excluded that the remaining balls in the urn might be all black or all white or that there are black balls there among the whites in some proportion or

other. There is no doubt we shall have better chances if we have made many draws, if, in other words, the sample was numerous, but in any case, we cannot do better than assign to a particular composition of the « mother population », a certain probability.

There are no doubt few engineers who have not suspected the hazards they are exposed to, one could even say the dangers, to judge by some specimens which are tested and often destroyed out of the remainder, which are rightly not tested at all. There is even, when one reflects on the conditions, something surprising in estimating by the help of a zero frequency (where all the specimens are perfect), a non-zero frequency, that is to say the proportion of bad specimens in the « mother population »; certain authors have even argued that in these conditions any estimation would be absurd and illusory.

What is certain is, that the few samples only give brief and illusory information and do not deserve for any reason whatever the confidence too often placed in the reports. On the other hand, numerous examples can give valuable information and we propose in what follows to show how they should be treated.

Validity of probability calculations.

Certain minds experience a natural distrust of probability calculations. (*Méfiance est mère de sûreté.* — Translator's note.) These people will no doubt say, let us admit that you have been able to calculate a probability, but accurate as may be the calculation, what does it signify? Whatever may be the pro-

bability that you attribute to the movement of a white ball when I draw, I shall draw a white ball or a black ball, so what then becomes of your probability? If trusting to your calculations, I stake on the white and it turns out to be a black ball, I should have lost my throw all the same. What does your probability indicate?

It is evident that we must come to an understanding. A probability is, as we have said, nothing else but the forecast of a frequency; thus a single draw cannot determine a frequency. So a single draw cannot verify a probability, apart from the limiting case where this probability is a certainty. On the other hand, if the fresh draws are repeated sufficiently often, we shall rediscover, in the frequency of the observed phenomenon, the frequency which was shown in the drawing of the sample. That is the only way to verify a probability.

Let us add, that in the case under discussion, if the sample selected which is taken from the « mother population » has to run the risk of being short in number, it is never so with the « mother population », samples remaining in all practical cases, relatively few in number compared to the supply from which they are chosen.

Certain other minds, which we will call realist and among which will be found a certain number of American colleagues, will perhaps ask themselves, to what practical conclusions these speculations on the reliability and on the calculations of probability may lead and what is the rule which they will follow.

The reply to these questions is as follows :

Let us consider a supply of industrial goods of any kind, intended to produce a given result.

If certain elements of this supply do not produce the result promised by the vendor and hoped for by the buyer, direct or indirect consequences will arise, which will have to be met by the latter, and may vary from a simple disagreement, up to catastrophes of the highest importance.

We will call the cost of the catastrophe A, whatever it may be, insignificant or considerable; we will designate by p the probability of failure of a portion of the supply, which failure will be capable of causing the catastrophe referred to.

The buyer could cover himself against the risk to which he will be exposed, by an insurance of : —

$$A \times p$$

and which will to that extent increase the buyers price.

The question may then arise, on behalf of this buyer, to know whether he would be inclined to buy goods of a better quality, costing a little more but having less probability of accident; for him the problem will be stated by comparing a certain number of totals such as :

$$F_i + A \times p_i$$

F_i indicating the price of a supply of given quality and p_i the probability corresponding to a catastrophe of which the cost is A and to find for this a minimum.

The parallel question will arise for the seller, to determine the cost price of goods for which he could guarantee that

they would not present a risk of failure (loss) greater than p_i .

The problem is thus set out in a clear and correct fashion as a function of a criterion as practical as possible since it is the economic criterion.

In this way, we have got at the heart of the matter and we have now to see how the probability p_i may be determined, on the one hand by the seller in order to establish his cost price and, on the other hand, by the buyer in order to control the quality of the goods which are supplied to him and the conformity of this quality with the specifications of his order.

It will be understood that the sources of information are essentially, for the seller as well as for the buyer, the results obtained by a test of p trials made on a sample of p units chosen from the supply under consideration which forms the mother population. It is in this « mother population » of M individuals, that we have to estimate what is the probability p_i that we shall encounter N defective parts or of which the characteristics, if they are measurable, are below a given value.

BAYES formula.

The precise problem to which we have definitely to turn our attention, is the problem known as the « probability of causes » of which the solution, due to BAYES, is demonstrated in all the cases dealing with the calculation of probabilities.

The arrangements of urns which fit this problem are as follows.

By adopting extreme simplification, let us consider 2 urns, each containing 10 balls, urn A contains 9 white balls and one black, urn B contains 9 black balls and one white. I draw a ball from one of 2 urns taken at random. This ball is white. What is the probability that this was made from urn A ?

Let us make a large number of similar draws, alternately from urn A and urn B, replacing every time in the urn the ball which was taken from it and simply noting its colour. It is evident that of 10 white balls drawn, 9 will come from urn A and 1 from urn B; the frequency of motion of a white ball from urn A is $9/10$. This frequency of draws already made will become the probability for a new draw; the reply to the question put is $9/10$.

Let us now consider a scheme a little more complicated including n urns containing white and black balls, the white balls being in the proportion p_1 in the first urn, in the proportion p_2 in the second, etc. I draw a white ball at random from one of the n urns, what is the probability p that this ball has been drawn from the first urn ?

The generalization of the reasoning already given at once gives the result :

$$p = \frac{p_1}{p_1 + p_2 + \dots + p_n}$$

Let us increase the complexity of our scheme by assuming that we have q_1 urns having the proportion p_1 of white balls, q_2 urns having the proportion p_2 of these same balls, etc. What is the probability that one white ball might have been drawn from an urn of type p_1 ? The

answer in virtue of the same reasoning, is evident :

$$p = \frac{p_1 q_1}{p_1 q_1 + p_2 q_2 + \dots + p_n q_n}$$

This is the BAYES formula.

The probability backers make the formula a little closer by changing the following terms :

a white ball is → realisation of the occurrence E.
drawn

urn No. 1 → cause C_1 .

proportion p_1 → probability of realisation of occurrence E due to cause C_1 .

number q_1 → probability of priority of action by cause C_1 .

probability p → probability a posteriori of cause C_1 being put in action to realise the occurrence E.

Clearly one can adopt either terminology or the other according to circumstances.

The probabilists continue to insist on the fact that à priori knowledge of the probabilities such as q_1 is absolutely necessary to enable one to calculate p . This necessity is evident and there is truly no way of avoiding it, whatever may be done about it; any of the artifices proposed in order to get over this need, can only mask the difficulty without solving it, since, short of knowing q_1, q_2, \dots, q_n , the problem remains indeterminate.

Case of supplies containing good and bad specimens.

Let us return to our actual problem and let us consider a supply of M specimens, of which N are bad. We select

from the « mother population » of M specimens which form the supply, a sample of p specimens. Let us calculate the probability that these p specimens are all good. This probability, according to a simple calculation of combinative analysis, is equal to :

$$\tilde{\omega} = \frac{C_{M-N}^p}{C_M^p} = \frac{(M-N)(M-N-1)\dots(M-N-p+1)}{M(M-1)\dots(M-p+1)}$$

By grouping terms of the same order in the numerator and denominator and assuming, as is usual, that p is small as against M , we can readily see that $\tilde{\omega}$ is approximately equal to :

$$\tilde{\omega} = \left(1 - \frac{N}{M}\right)^p$$

we shall, in the same way, calculate the values of $\tilde{\omega}$ corresponding to different values of $\frac{N}{M}$.

If we consider then $\frac{N}{M}$ as unknown and if one wishes, having first made a selection of p specimens which have all been shown to be good, to know the probability that $\frac{N}{M}$ has a given value, one might apply BAYES' formula on condition that :

1) one can make out a list of values of $\frac{N}{M}$ which may be considered as possibilities;

2) to assign to each of these possible values a certain coefficient of probability.

Certain probability supporters were frightened by this two-fold condition, into declaring that the BAYES formula was inapplicable and practically valueless and it was then that they proposed various methods which, apparently, got over the difficulty, but the advantages of which are not and could not be other than illusory.

It is moreover not so difficult, with a little practice, to adopt the double condition which has been indicated, in the greater number of cases occurring in practice, and it should be noted moreover that it is not at all necessary in this case to obtain very great precision. Simple orders of sufficient size often give information which is not without value and suffice to summarize the information, necessarily limited of tests on samples.

The tables given further on will, we think, illustrate these remarks.

We will suppose, for example, that we are confronted by a supply of which we know nothing and in which the proportion of bad specimens $\frac{N}{M}$ may have any value whatsoever. We should then examine the proportions of bad specimens set out in series (RENARD), i. e. in geometric progression over a range $\sqrt[10]{10}$ from 0.8 up to 0.001 and we shall admit that these various values of $\frac{N}{M}$ are all equally probable. Let us consider, on the other hand, specimens of which the effective, actual value p may have different values, running in arithmetic progression, in ratio 1, from 1 to

6, and in ratio 2, from 6 tot 12, then in series RENARD 16 up to 1 000.

In that case the probability is readily calculated :

$$\tilde{\omega} = \left(1 - \frac{N}{M}\right)^p$$

for the different values thus selected of $\frac{N}{M}$ and of p .

It is easy then to apply the BAYES formula and to calculate, after admitting that a sample of p parts has given these p good parts, what is the probability that the mother population will show a proportion of bad parts equal to a particular value of $\frac{N}{M}$ or superior than that same value; the difference with the unit of this integral probability, be it well understood, will give a probability that the mother population will show a proportion of bad specimens inferior to the particular value under consideration.

The tables and the networks of curves given further on summarize these calculations, which are extremely long but not particularly difficult.

If one admits that the sample presents p good specimens and one bad one, the calculations are slightly complicated and become more laborious, but without being more difficult; we then have :

$$\tilde{\omega} = C_p^1 \frac{N}{M} \left(1 - \frac{N}{M}\right)^p$$

and if the sample gives us p good specimens and 2 bad ones :

$$\tilde{\omega} = C_p^2 \left(\frac{N}{M}\right)^2 \left(1 - \frac{N}{M}\right)^p$$

The following calculations develop as before. Similarly the tables and families of curves which carry on the calculation are given hereafter.

Case of supplies where the quality is expressed by a number.

The quality of certain goods is a question of all or nothing and these goods, which may be divided into two classes, good and bad, were made the object of the preceding calculations.

The quality of certain goods however, shows itself as a measurable characteristic and is, therefore, expressed by a number.

This distinction, apparently very simple, however calls for a few remarks. Firstly, we may note that the same goods can, in certain respects, enter the first category and certain others into the second.

Thus an electric lamp illuminates or does not illuminate, so that then it is good or bad; but if it illuminates, one may consider its brilliance, its consumption, its life, etc., all of which are measurable qualities and which will be expressed by a number.

In other respects, the classification into good and bad specimens, may indirectly result in a measurement and in the consideration of a minimum threshold value and of a maximum threshold value.

Finally it is hardly necessary to say that, in many cases the fact for one specimen to be good or bad, is purely a question of appreciation on the part of the buyer; a bad specimen for a given purpose may be good for another.

When we consider a measurable cha-

racteristic such as: chemical composition, mechanical strength, viscosity, etc. a series of questions may arise concerning the definition of quality of the goods under review, choice of the quality suitable for a predetermined purpose and for controlling the quality demanded by the user from his supplier. These various questions can only be settled by statistical and probability methods, similar to those which are evidenced in the case of good and bad specimens.

In the case of a similar supply, the accident takes place when the characteristic considered reaches, e. g. a value below a certain minimum — and it is there that the difficulty is met — it is rarely possible to make measurement of the whole supply, either because the tests are destructive of the goods supplied or because they are costly. One is therefore obliged to measure the characteristic only on a sample lot of p specimens, or p pinches, or p test bars, and the problem is as before, to conclude from the results of the tests, facts concerning the mother population from which the samples were chosen.

We shall admit that the measurements on the sample, will have given a collection of values more or less dispersed, which may be stated in résumé, as a mean value M and by a mean quadratic divergence Q (1).

(1) The reader who might desire further particulars on this aspect of the subject could refer to our recent article published in *Travaux* and which is clearly illustrated, by a consideration of works executed in concrete.

Marcel PROT, « The rational determination and control of safety coefficients », review *Travaux*, Editions Sciences et Industrie, 6, avenue Pierre 1^{er} de Serbie, Paris.

With the help of values M and Q , and taking into consideration the number of the sample p , one can as we shall see in a moment, estimate the mean value M' and the quadratic divergence Q' of the different values of the characteristic under consideration respecting the whole of the sample.

One can then, by means of certain generally verified hypotheses, calculate the probability r_i of the value considered as critical, i. e. susceptible of causing an accident. This probability, guaranteed by the seller, determines his price; the buyer, has on principle only to check it.

Hence-forward, the user has all the necessary information for applying economic criticism, namely:

thro' F_i the cost of the goods corresponding to the probability r_i ;

thro' A the cost of the catastrophe under probability r ;

thro' G the cost of the acceptance tests,

there remains only to establish, according to the different likely cases, what is the minimum total:

$$F_i + Ar_i + G$$

The calculation of the probability r_i is readily made with the help of tables for the function Θ if we can admit that the distribution of the values of the characteristic considered in the mother population follows, at least approximately, a law of LAPLACE-GAUSS. Now this law is very frequently verified and we have shown, some time ago already ⁽¹⁾,

⁽¹⁾ See Marcel PROT, « Note on the composition of errors », *Travaux et mémoires de la Société française des mécaniciens*, Vol. I, p. 40, Paris, 1939.

that it is enough, that a phenomenon should be considered, as the sum of 3 or 4 elementary phenomena of the same weight and equal probability, in order to obtain a distribution which approaches, in a strangely complete way, to a normal distribution, within already relatively extended limits.

If we take the normal law as having the form:

$$\Theta(u) = \frac{1}{\sqrt{2\pi}} \int_0^u e^{-\frac{u^2}{2}} du$$

the (reduced) divergence is equal to the mean quadratic divergence and it suffices in order to obtain the probability corresponding to a given value, to calculate by how many mean quadratic divergences this value diverges from the mean.

The calculations for estimating M' and Q' with the help of M , of Q and of p , without being really difficult are a little more tricky and we cannot develop them without exceeding the framework of this article; we shall confine ourselves to indicating in the form of tables and curves the results of the formulae given by M. Maurice DUMAS ⁽¹⁾.

The first of these tables, indicates for different values of p , what is the probability of a divergence between the mean M' of the mother population and the mean M of the sample, equal to K

⁽¹⁾ Maurice DUMAS, « Note on a series of measurements connected with a law by GAUSS », *Mémorial de l'Artillerie française*, 1937.

Maurice DUMAS and P. MAHEU, « Statistical methods and their applications in the domain of industrial technology », *Mémorial de l'Artillerie française*, 1948-1949, 1 vol., 600 p. Eyrolles, Paris, 1950.

times the mean quadratic divergence of the sample. One sees that with a sample of 12 units ($p = 12$) one has a quasi-certainty (prob. = 0.99) that $M - M'$ will not exceed Q , whereas with a sample of 2 units one has 1 chance in 2 (prob. = 0.5) for $M - M'$ to exceed Q and 1 chance in 10 that this divergence will exceed 6 or 7 Q .

The second of these tables, shows for different values of p , what is the probability of a mean quadratic divergence Q' of the mother population less than K times the mean quadratic divergence Q of the sample. It is evident that with a sample of 12 units one has the quasi-certitude that $Q' \leq 2 Q$ whereas with a sample of 2 units one has a probability 0.12 that $Q' > 10 Q$ and a probability of close on 0.3 in order that $Q' > 3.5$ or 4 Q .

These tables, as also the networks of curves which interpret them, should enable, we think, the solution, without difficulty and with sufficient accuracy, of the majority of the problems concerning the safety of structures and control of the quality of materials supplied.

Conducting the tests — Counter survey — Progressive tests.

The specifications are fixed by tradition in most countries, the number of acceptance tests at 2 or 3 per lot, exceptionally at 5 or 6 per lot, the number is hardly ever greater. Certain specifications provide for a check test when the test results are unfavourable.

This practice is in many respects, subject to serious criticism and in some cases is quite absurd.

It is enough to consider the formula established earlier :

$$\bar{\omega} = \left(1 - \frac{N}{M}\right)^p$$

and analogous formulae to realise that the probability of constitution of a given sample depends only on the proportion $\frac{N}{M}$, not on the proportion $\frac{p}{M}$.

If then we divide a supply in lots and if one fixes the strength of the samples per lot, this amounts in the end in fixing a value for $\frac{p}{M}$, which is irrational, favourable to the seller but unfavourable to the buyer.

If, on the other hand, a sample consists only of a few units it will suffice to consider for a moment the different tables attached to this investigation in order to be able to see that the proof (or test) is entirely illusory and practically without any significance, so great is the uncertainty of the conclusions which it will allow us to form.

We do not insist on the check test which consists purely and simply in repeating a test which was unfavourable to the vendor on the pretext that it was a question of a fluke. This is truly childishness, since the same argument could equally well justify a demand for a check test by the buyer, every time the test had been in favour of the seller.

If the buyer had rationally fixed the conditions for acceptance or, in other words, for quality control, supported by the various considerations preceding the tests, is it likely he will forego these con-

ditions while the test is being carried out?

One could undoubtedly consider as reasonable not a « check test » but a « complementary test » such that the sum of the two tests should be neither more nor less severe than the original test.

For example : Let us suppose that a buyer wished to have only one chance in 100 of receiving a supply containing more than 10 % of bad specimens : table No. 3 shows that he will need a sample of about 24 specimens, all of which should be faultless. If the 24th specimen is bad, the matter could be considered unfortunate and one could, in view of the fact that the desired result could be assured by a sample of about 50 specimens of which one would be bad, decide to choose 25 new specimens which if they are all perfect, would make acceptance of the supply possible (Table 5).

It is true that in these conditions, the severity of the control is not changed, but the price of the control would be doubled. The matter is not without importance.

It may however be noted, that if the rule for acceptance is that 25 selected specimens should all be good, the fact of finding at once 2 or 3 bad specimens, practically makes the case hopeless and allows the matter to be finished with, without going on with the test and the costs involved.

It therefore appears to be reasonable to set out a programme of tests by fixing, not a minimum of tests with, possibly, complementary tests, but rather a maxi-

mum programme which one would interrupt, without completing the programme, when it is clear that the supply cannot be accepted.

It may be mentioned however, that not all goods suit this type of test, which may be called progressive. This would be the case, for example, with test pieces of concrete (cement), which must be tested after 1 week, 4 weeks or even 3 months after setting. Without going so far as this extreme case, the progressive test is not very practical, when it is necessary to prepare test pieces and to send them to the laboratory for testing; it is then generally preferable to fix a rational programme once for all and to carry it out to the end.

Conclusions.

The question which we have discussed in the preceding pages is of extreme practical importance and, moreover too little known, it is likewise complicated and tricky and we have been obliged, in regard to many points, to limit our remarks to a few summary indications. We think however, we have touched on all sides of the question and have at least, drawn the attention of certain readers to some problems, the importance of which they perhaps do not appreciate at their true value.

Our study may be summarised by the following conclusions :

1. — The results obtained by the help of a test of p experiments may not be considered as an exact representation of the supply from which the sample has been chosen. In order to obtain this representation, it is necessary to interpret

the results of the test and to calculate an estimate taking into account the number of trials made, a calculation, the more exact the greater the value of p .

2. — The determination of the number of trials forming a complete test can only be rationally fixed by the buyer of the supply in question, considering the safety he desires to secure and the risk of which he proposes to limit the probability.

3. — The number of trials forming a test should not be proportional to the importance of the supply under consideration; the severity of control is only a function of the number of trials forming the test. To divide a supply into a number of lots, larger or smaller, and to proportion the number of trials to the importance of the lots, works out, in short, to a notable reduction in the severity of the test.

4. — To proceed with tests, which only include some trials, will in general add nothing to the information on the goods which can be obtained elsewhere and will only provide extremely summary and practically illusory information in the majority of cases.

5. — The tests on samples will be adequately complete, when this can be effected, by inspections, even summary ones, bearing on the whole of the supply.

Tables and networks of curves.

1. — Probability of formation of a sample of p good specimens out of a mother population containing $\frac{N}{M}$ bad specimens. (Table.)

2. — Ditto. (Network of curves.)

3. — Composition of a mother population estimated with the help of a sample of p good specimens. (Table.)

4. — Ditto. (Network of curves.)

5. — Composition of a mother population estimated with the help of a sample of p good specimens + 1 bad specimen. (Table.)

6. — Ditto. (Network of curves.)

7. — Composition of a mother population estimated with the help of a sample of p good specimens + 2 bad specimens. (Table.)

8. — Ditto. (Network of curves.)

9. — Probability of a divergence between the mean M' of a mother population and the mean M of a sample of p units less than K_1 times the mean quadratic divergence Q of the sample. (Table.)

10. — Ditto. (Network of curves.)

11. — Probability of a mean quadratic divergence Q' of the mother population less than K_2 times the mean quadratic divergence Q of a sample of p units. (Table.)

12. — Ditto. (Network of curves.)

BIBLIOGRAPHY.

By M. MARCEL PROT :

NOTE ON THE NOTION OF THE COEFFICIENT OF SECURITY.

Annales des Ponts et Chaussées, 1936, t. II, fasc. 7.

SIGNIFICATION AND UTILISATION OF TESTS ON SAMPLES.

Conférences de l'Ecole Nationale des Ponts et Chaussées, 1942-1943;

Circulaire, série 1, n° 6, de l'Institut Technique du Bâtiment et des Travaux Publics, mai 1942.

THE SECURITY OF STRUCTURES. INTRODUCTORY REPORT.

Publications préliminaires du III^e Congrès International des Ponts et Charpentes (Liège, 1948), p. 571.

SECURITY.

Annales des Ponts et Chaussées, 119^e année, n° 1, janvier 1949, p. 19.

STATISTICAL TESTS ON CEMENT AND CONCRETE.

Annales de l'Institut du Bâtiment et des Travaux Publics. Nouvelle série. « Béton et béton armé », n° 8, juillet-août 1949; « Rapport final du III^e Congrès International des Ponts et Charpentes » (Liège, 1949), p. 701.

STATISTICS AND SECURITY.

Revue de Métallurgie, 46^e année, n° 11, novembre 1949, p. 716.

THE SAFETY OF STRUCTURES.

« Actes du Colloque International de Mécanique de Poitiers » (1950), t. IV; « Publications Scientifiques et Techniques du Ministère de l'Air », n° 261, p. 145.

THE PROBABILIST THESIS OF SECURITY.

Annales des Travaux Publics de Belgique, 103^e année, 4^e fascicule, août 1952, p. 519-539.

DEFINITION, CHOICE AND CONTROL OF THE QUALITY OF MATERIALS.

Revue des Matériaux de Construction et de Travaux Publics.

By MARCEL PROT and ROBERT LEVI :

MODERN IDEAS ON THE SECURITY OF STRUCTURES.

Revue Générale des Chemins de fer, juin 1951.

By MICHEL BONNET, Ingénieur des Ponts et Chaussées:

EXPERIMENTAL STUDY ON THE QUALITY OF THE CONCRETE USED IN THE RECONSTRUCTION OF THE VILLENEUVE-ST.-GEORGES BRIDGE OVER THE SEINE.

Annales des Ponts et Chaussées, 1953.

THE VILLENEUVE-ST.-GEORGES BRIDGE. THE LESSONS LEARNT REGARDING CONTROL OF THE QUALITY OF MATERIALS.

Annales de l'Institut Technique du Bâtiment et des Travaux Publics.

By MAURICE DUMAS :

NOTE ON THE SERIES OF MEASURES BELONGING TO A LAW OF GAUSS.

« Mémorial de l'Artillerie française », 1937.

APPLICATION OF STATISTICAL METHODS TO THE INTERPRETATION OF TESTS ON SAMPLES.

« Travaux et Mémoires de la Société française de Mécaniciens » (1939).

INTRODUCTION OF PROBABILITIES IN THE FIELD OF THE STRENGTH OF MATERIALS.

Annales des Ponts et Chaussées, 1947.

PRINCIPLES OF THE APPLICATION OF STATISTICAL METHODS TO PRODUCTION AND RESEARCH.

One volume, 130 pages, published by Eyrolles.

By M. DUMAS and P. MAHEU :

STATISTICAL METHODS AND THEIR APPLICATION IN THE FIELD OF INDUSTRIAL TECHNIQUE.

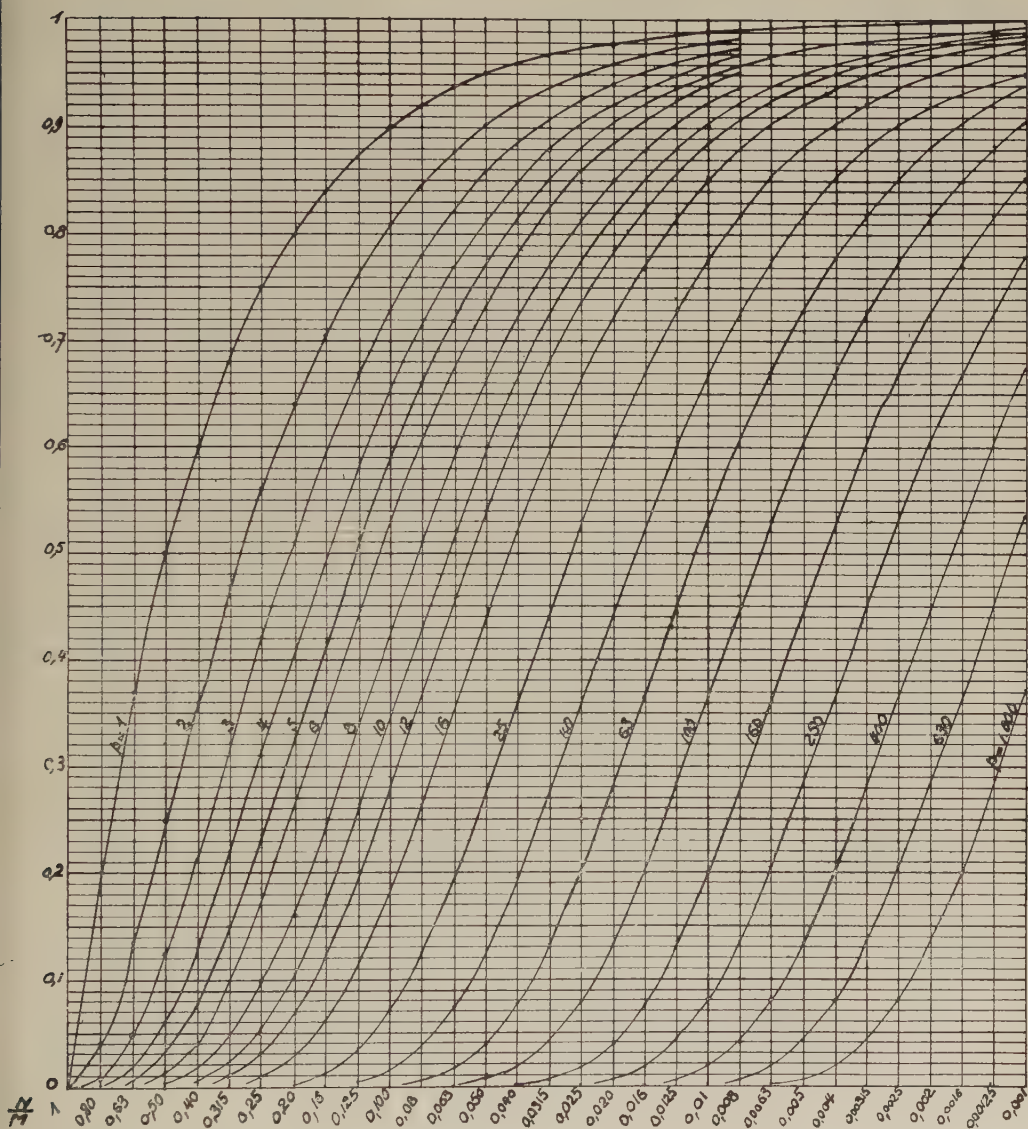
One volume, 600 pages to be published by Eyrolles.

Published in the « Mémorial de l'Artillerie française » (Fascicules II and IV of 1948, Fascicule III of 1949).

1. Probability of formation of a sample of p good specimens out of a mother population containing $\frac{N}{M}$ bad specimens.

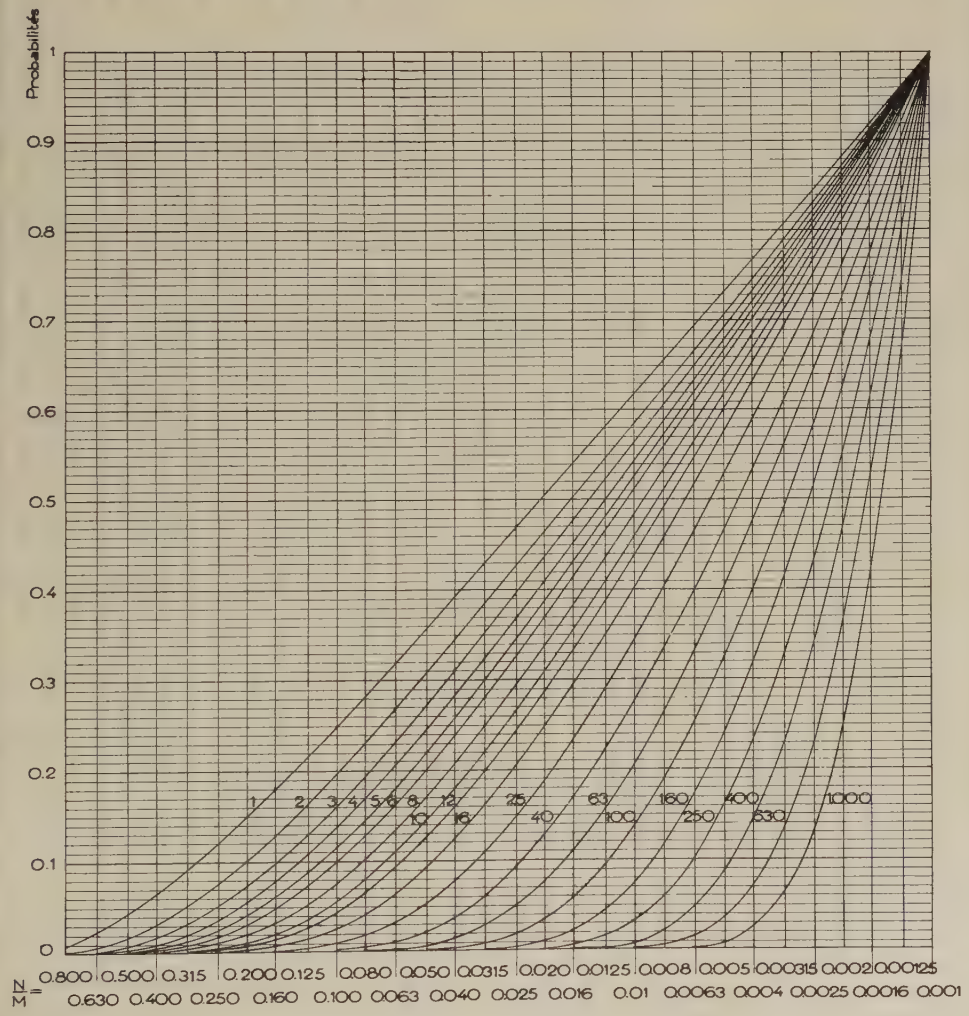
$\frac{N}{M}$ \ P	1	2	3	4	5	6	8	10	12	16	25	40	63	100	150	250	400	630	1000
0.800	0.20	0.04	0.01																
0.630	0.37	0.14	0.05	0.02	0.01														
0.500	0.50	0.25	0.12	0.06	0.03	0.01													
0.400	0.60	0.36	0.22	0.13	0.08	0.05	0.02	0.01											
0.315	0.68	0.47	0.32	0.22	0.15	0.10	0.05	0.02	0.01										
0.250	0.75	0.56	0.42	0.32	0.24	0.18	0.10	0.06	0.03	0.01									
0.200	0.80	0.64	0.51	0.41	0.33	0.26	0.17	0.11	0.07	0.03									
0.160	0.84	0.70	0.59	0.50	0.42	0.35	0.25	0.17	0.12	0.06	0.01								
0.125	0.87	0.76	0.67	0.59	0.51	0.45	0.34	0.26	0.20	0.12	0.03								
0.100	0.90	0.81	0.73	0.66	0.59	0.53	0.43	0.35	0.28	0.18	0.07	0.01							
0.080	0.92	0.85	0.78	0.71	0.66	0.61	0.51	0.43	0.37	0.26	0.12	0.03	0.01						
0.063	0.94	0.88	0.82	0.77	0.72	0.68	0.59	0.52	0.46	0.35	0.20	0.07	0.02						
0.050	0.95	0.90	0.86	0.81	0.77	0.73	0.65	0.60	0.54	0.44	0.28	0.13	0.04						
0.040	0.96	0.92	0.88	0.85	0.81	0.78	0.72	0.66	0.61	0.52	0.36	0.19	0.08	0.02					
0.0315	0.97	0.94	0.91	0.88	0.85	0.82	0.77	0.73	0.68	0.60	0.45	0.28	0.13	0.04	0.01				
0.025	0.97	0.95	0.93	0.90	0.88	0.86	0.82	0.78	0.74	0.67	0.53	0.36	0.20	0.08	0.02				
0.020	0.98	0.96	0.94	0.92	0.90	0.88	0.85	0.82	0.78	0.72	0.60	0.44	0.28	0.13	0.04				
0.016	0.98	0.97	0.95	0.94	0.92	0.91	0.88	0.85	0.82	0.77	0.67	0.52	0.36	0.20	0.07	0.02			
0.0125	0.99	0.97	0.96	0.95	0.94	0.93	0.90	0.88	0.86	0.82	0.73	0.60	0.45	0.28	0.13	0.04	0.01		
0.0100	0.99	0.98	0.97	0.96	0.95	0.94	0.92	0.90	0.89	0.85	0.78	0.67	0.53	0.37	0.20	0.08	0.02	0.01	
0.0080	0.99	0.98	0.98	0.97	0.96	0.95	0.94	0.92	0.91	0.88	0.82	0.72	0.60	0.45	0.28	0.13	0.04	0.01	
0.0063	0.99	0.99	0.98	0.97	0.97	0.96	0.95	0.94	0.93	0.90	0.85	0.78	0.67	0.53	0.36	0.21	0.08	0.02	0.01
0.0050	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.95	0.94	0.92	0.88	0.82	0.73	0.60	0.45	0.28	0.13	0.04	0.01
0.0040	1.00	0.99	0.99	0.98	0.98	0.98	0.97	0.96	0.95	0.94	0.90	0.85	0.78	0.67	0.53	0.37	0.20	0.08	0.02
0.00315	1.00	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.95	0.92	0.88	0.82	0.73	0.60	0.45	0.28	0.14	0.04
0.00250	1.00	0.99	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.94	0.90	0.85	0.78	0.67	0.53	0.37	0.20	0.08
0.00200	1.00	1.00	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.97	0.95	0.92	0.88	0.82	0.72	0.61	0.45	0.28	0.13
0.00160	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.97	0.96	0.94	0.90	0.85	0.77	0.67	0.52	0.36	0.20
0.00125	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.97	0.95	0.92	0.88	0.82	0.72	0.61	0.46	0.29
0.001	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98	0.97	0.96	0.94	0.90	0.85	0.78	0.67	0.53	0.37

2. - Probability of formation of a sample of p good specimens out of a mother population containing $\frac{N}{M}$ bad specimens.



4. — Composition of a mother population estimated with the help of a sample of p good specimens.

This table gives the probability so that the mother population shows a proportion of bad specimens superior to $\frac{N}{M}$.



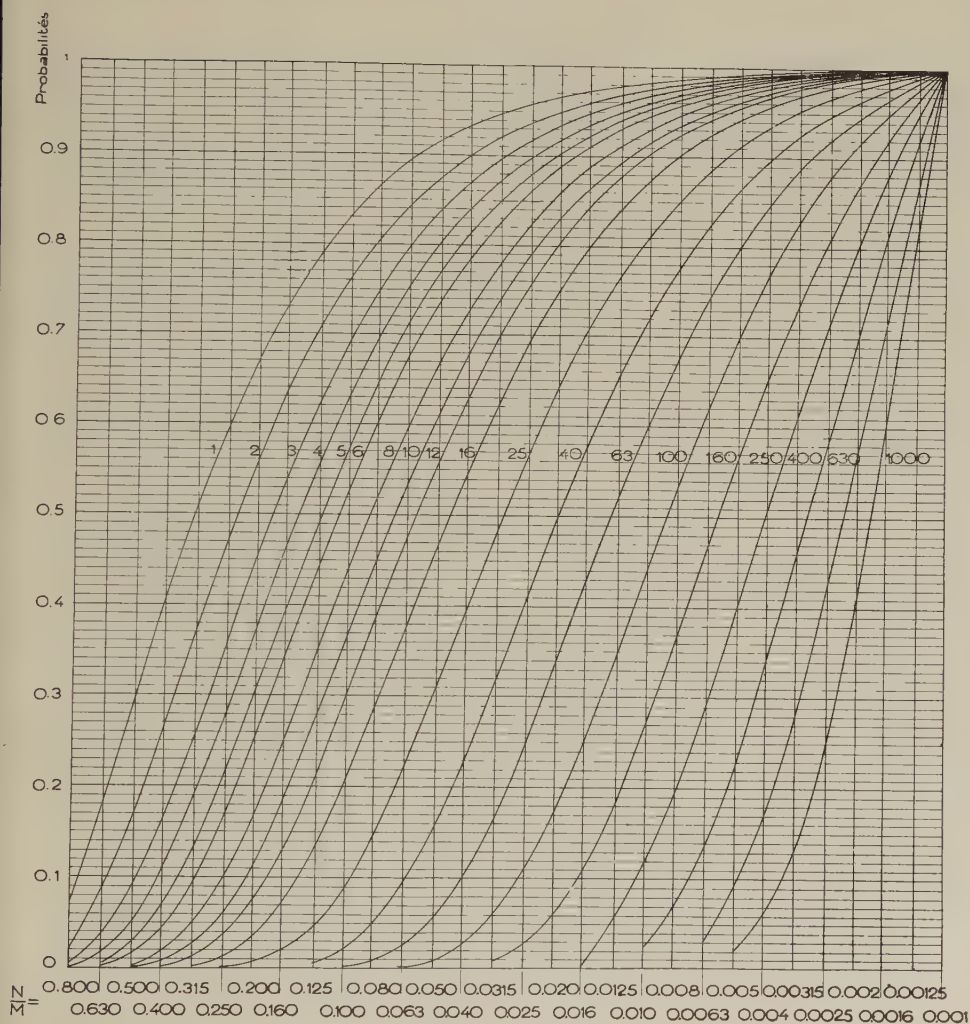
5. — Composition of a mother population estimated with the help of a sample p good specimens plus one bad specimen.

This table gives the probability so that the mother population shows a proportion of bad specimens superior to $\frac{N}{M}$.

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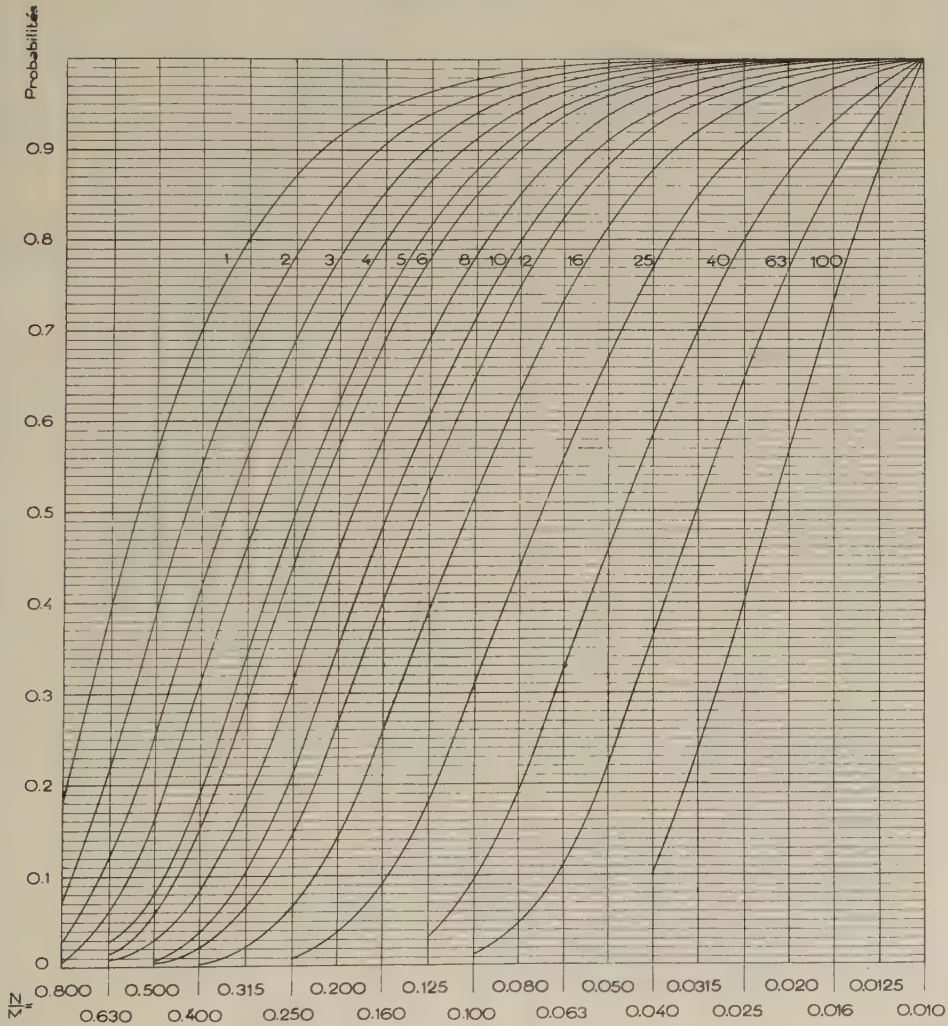
6. — Composition of a mother population estimated with the help of a sample p good specimens plus one bad specimen.

This table gives the probability so that the mother population shows a proportion of bad specimens superior to $\frac{N}{M}$.



8. — Composition of a mother population estimated with the help of a sample of p good specimens plus two bad specimens.

This table gives the probability so that the mother population shows a proportion of bad specimens superior to $\frac{N}{M}$.



A theoretical study of vertical movements in a bogie vehicle,

by A. PILLEPICH,

Ingénieur en Chef des Services Techniques de la Compagnie Internationale des Wagons-Lits et des Grands Express Européens.
(Revue Générale des Chemins de fer.)

The theoretical study of the conditions that must be satisfied in order to improve comfort in railway vehicles is complicated by the fact that it is difficult to give a physiological definition of comfort. It is known that the human body is not very sensitive to phenomena of a frequency higher than 10 whereas frequencies of the order of 5 have a very disagreeable effect since they correspond approximately to the reflex time of the organism. Frequencies of from 1 to 1½ per second are usually tolerable if of moderate amplitude but if the frequency is further reduced the unpleasant physiological symptoms reappear. Again, the sensation of discomfort will vary from one traveller to another.

However, there exist empirical formulæ which relate comfort to the amplitude of movement and its frequency (1). It is therefore of interest to be able to determine in advance, by calculation, the characteristics of the diverse movements to which the vehicle will be subject.

Two investigations of vertical movement only have been made, one by M. Pillepich, Ingénieur en Chef des Services Techniques de la Compagnie Internationale des Wagons-Lits, relating to vehicles provided with two-stage suspension, and the other by M. Chartet of the Research Department, S.N.C.F., dealing with single suspension. The results of the study by M. Pillepich are given below and those of M. Chartet were published in the Revue Générale, for November 1952.

M. Pillepich has calculated first of all the vertical displacement of different points in a vehicle with double suspension, in the absence of friction. Assuming that the track offers differences of level of the same periodicity as the joints, M. Pillepich has revealed the existence of critical speeds lying within the range of normal running speeds.

Following upon this M. Pillepich has allowed for the damping action of the springs and has shown that a complete solution can be found for the appropriate differential equations in the case where both stages of the suspension are damped to an extent represented by a coefficient which is proportional to the spring and the speed of deflection, and inversely proportional to the static spring rate.

(1) N. D. C. R. — For example, the following is the formula commonly used by the German Railways :

$$NQ = 2.7 \sqrt[10]{a^3 f^5}$$

where NQ is a « ranking characteristic » assigned to the riding of the vehicle,

a the amplitude of movement, i.e. with respect to the median value of the effective oscillations of the vehicle body,

f the frequency.

The characteristic is considered to be « very good » when it equals unity; « good » at a value of 2, and increasingly unfavourable as it exceeds this figure. A value of 4 is merely « tolerable » and 5 is regarded as « dangerous ».

The French Railways employ an expression of the form af^2 .

The author shows that according to this hypothesis the critical amplitude of oscillation is reduced by damping and that there is advantage in applying vigorous damping to the springs while at the same time increasing their flexibility.

The following pages contain numerous formulæ which may at first sight appear cumbersome by reason of the number of terms essential to the geometrical definition of the position, in space, of a bogie vehicle. Actually however they relate only to current notions concerning the equilibrium of forces and their interpretation is clearly set out.

INTRODUCTION

In the present note we shall study the vertical movements of a coach mounted on bogies and running on normal track.

It will be assumed that the track is straight, and level, and that both rails have the same characteristics, that is, the same irregularities with respect to the horizontal.

The vehicle will be assumed to be with the normal type W.L. bogie with two stages of suspension; helical springs between the equaliser and the bogie itself, and elliptical springs between the bogie and the bolster.

It will be assumed that the springs deflect proportionally to the load and that they are frictionless; also, that the weights both of the superstructure and the bogies are uniformly distributed throughout their lengths.

We shall completely disregard lateral movements: rocking (or rolling) i.e. oscillation about the longitudinal axis and nosing, or oscillation about the vertical axis.

In the first part the problem will be examined in its broader aspect, from the mathematical point of view. In the second part the results so calculated will be applied to the case of track containing irregularities that repeat periodically.

The third part will comprise the discussion of the results obtained and the inferences to be drawn therefrom.

In the fourth part we shall study the damping effect of the springs, the internal friction or damping of which have been neglected in the preceding calculations.

FIRST PART

GENERAL EQUATIONS OF MOTION

The problem consists in determining, as a function of time t , the values of the six variables $X \propto x_1 \alpha_1 x_2 \alpha_2$ (defined in fig. 1) which determine the position in space of all points of the coach body or the bogies.

CALCULATION OF THE FORCES AT WORK

a) Height of springs, expressed in terms of the variables.

The following formulae are readily derived, being simple geometrical relationships between the different notations of fig. 1:

$$l_1 - l' = x_1 - b\alpha_1 - z_1 \frac{d+b}{2d} - z_2 \frac{d-b}{2d}$$

$$l_2 - l' = x_1 + b\alpha_1 - z_1 \frac{d-b}{2d} - z_2 \frac{d+b}{2d}$$

$$l_3 - l' = x_2 - b\alpha_2 - z_3 \frac{d+b}{2d} - z_4 \frac{d-b}{2d}$$

$$l_4 - l' = x_2 + b\alpha_2 - z_3 \frac{d-b}{2d} - z_4 \frac{d+b}{2d}$$

$$L_1 - L' = X - B\alpha - x_1$$

$$L_2 - L' = X + B\alpha - x_2$$

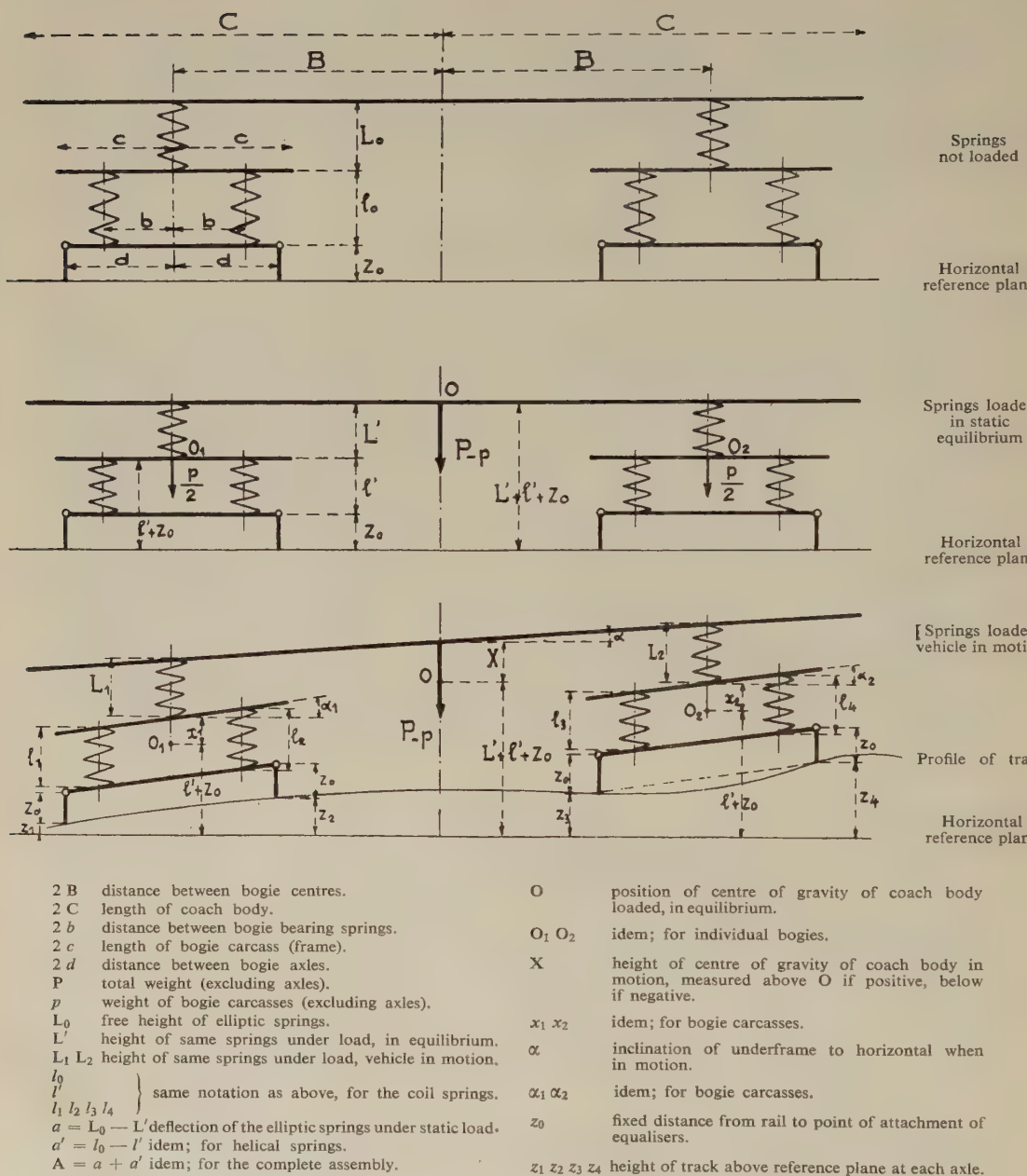


Fig. 1

b) Compressive load on springs.

The load f_1 on say spring l_1 is given by the formula :

$$\frac{f_1}{l_0 - l_1} = \frac{\frac{P}{4}}{l_0 - l'}$$

which expresses the relationship between compressive load and deflection.

Now

$$l_0 = l' + a'$$

whence :

$$f_1 = \frac{P}{4a'} (a' + l' - l_1)$$

where the quantity $l' - l_1$ is given by one of the formulae above.

The following compressive loads $f_1 f_2 f_3 f_4$ $F_1 F_2$ are finally obtained for springs of heights $l_1 l_2 l_3 l_4$ $L_1 L_2$ respectively :

$$f_1 = \frac{P}{4a'} \left(a' - x_1 + b\alpha_1 + z_1 \frac{d+b}{2d} + z_2 \frac{d-b}{2d} \right)$$

$$f_2 = \frac{P}{4a'} \left(a' - x_1 - b\alpha_1 + z_1 \frac{d-b}{2d} + z_2 \frac{d+b}{2d} \right)$$

$$f_3 = \frac{P}{4a'} \left(a' - x_2 + b\alpha_2 + z_3 \frac{d+b}{2d} + z_4 \frac{d-b}{2d} \right)$$

$$f_4 = \frac{P}{4a'} \left(a' - x_2 - b\alpha_2 + z_3 \frac{d-b}{2d} + z_4 \frac{d+b}{2d} \right)$$

$$F_1 = \frac{P-p}{2a} (a - X + B\alpha + x_1)$$

$$F_2 = \frac{P-p}{2a} (a - X - B\alpha + x_2)$$

SETTING UP THE EQUATIONS

For the coach body on the one hand and the individual bogies on the other, we shall put the sum of the forces at work equal to the sum of the elementary masses multiplied by their acceleration.

The vertical projections of these three relationships together with their moments about the three respective centres of gravity are expressed in the six equations :

$$\frac{p}{g} x''_1 + \frac{AP - a'p}{aa'} x_1 - \frac{P-p}{a} X + \frac{P-p}{a} B\alpha = \frac{P}{a'} \frac{z_1 + z_2}{2}$$

$$\frac{p}{g} x''_2 + \frac{AP - a'p}{aa'} x_2 - \frac{P-p}{a} X - \frac{P-p}{a} B\alpha = \frac{P}{a'} \frac{z_3 + z_4}{2}$$

$$\frac{p}{3g} \alpha''_1 + \frac{P}{a'} \frac{b^2}{c^2} \alpha_1 = - \frac{P}{a'} \frac{b^2}{c^2} \frac{z_1 - z_2}{2d}$$

$$\frac{p}{3g} \alpha''_2 + \frac{P}{a'} \frac{b_2}{c_2} \alpha_2 = - \frac{P}{a'} \frac{b^2}{c^2} \frac{z_3 - z_4}{2d}$$

$$\frac{a}{g} X'' + X = \frac{x_1 + x_2}{2}$$

$$\frac{a}{3g} \frac{C^2}{B^2} B\alpha'' + B\alpha = - \frac{x_1 - x_2}{2}$$

SOLUTION OF THE EQUATIONS

The foregoing equations are easily transformed as follows :

$$[1] \frac{aa'}{g^2} \frac{p}{P} X''' + \frac{A}{g} X'' + X = \frac{z_1 + z_2 + z_3 + z_4}{4}$$

$$[2] \frac{aa'}{g^2} \frac{p}{P} \frac{C^2}{3B^2} B\alpha''' + \frac{1}{g} \frac{C^2}{3B^2} \left[A + a' \frac{p}{P} \left(\frac{3B^2}{C^2} - 1 \right) \right] B\alpha'' + B\alpha = - \frac{z_1 + z_2 - z_3 - z_4}{4}$$

$$[3] x_1 = \frac{a}{g} X'' + X - \frac{a}{g} \frac{C^2}{3B^2} B\alpha'' - B\alpha$$

$$[4] x_2 = \frac{a}{g} X'' + X + \frac{a}{g} \frac{C^2}{3B^2} B\alpha'' + B\alpha$$

$$[5] \frac{a'}{g} \frac{p}{P} \frac{c^2}{3b^2} d\alpha''_1 + d\alpha_1 = - \frac{z_1 - z_2}{2}$$

$$[6] \frac{a'}{g} \frac{p}{P} \frac{c^2}{3b^2} d\alpha''_2 + d\alpha_2 = - \frac{z_3 - z_4}{2}$$

Equations [1] and [2] are of the 4th degree but bi-quadratic and may be solved for X and α after which equations [3] and [4] will give x_1 and x_2 . Finally, equations [5] and [6] lead directly to α_1 and α_2 .

If we designate individual solution of equations [1], [2], [5] and [6] by the symbols $\varphi \psi \omega_1 \omega_2$ and introduce the twelve constants $D E F G L M N R S_1 S_1' S_2 S_2'$ whose values are determined by the initial values of $X \alpha x_1 \alpha_1 x_2 \alpha_2$ and their derivatives, we may write down equations [7] to [12] which are the general equations of motion of the coach, body and bogies.

These equations provide a complete solution of the problem.

$$[7] X = D \cos mt + E \sin mt + F \cos nt + G \sin nt + \varphi$$

$$[8] B\alpha = L \cos m't + M \sin m't + N \cos n't + R \sin n't + \psi$$

$$[9] \quad x_1 = \begin{cases} + \left(1 - \frac{a}{g} m^2\right) (D \cos mt + E \sin mt) + \left(1 - \frac{a}{g} n^2\right) (F \cos nt + G \sin nt) + \varphi + \frac{a}{g} \varphi'' \\ - \left(1 - \frac{a}{g} \frac{C^2}{3B^2} m'^2\right) (L \cos m't + M \sin m't) - \left(1 - \frac{a}{g} \frac{C^2}{3B^2} n'^2\right) (N \cos n't + R \sin n't) \\ - \psi - \frac{a}{g} \frac{C^2}{3B^2} \psi'' \end{cases}$$

$$[10] \quad x_2 = \begin{cases} + \left(1 - \frac{a}{g} m^2\right) (D \cos mt + E \sin mt) + \left(1 - \frac{a}{g} n^2\right) (F \cos nt + G \sin nt) + \varphi + \frac{a}{g} \varphi'' \\ + \left(1 - \frac{a}{g} \frac{C^2}{3B^2} m'^2\right) (L \cos m't + M \sin m't) + \left(1 - \frac{a}{g} \frac{C^2}{3B^2} n'^2\right) (N \cos n't + R \sin n't) \\ + \psi + \frac{a}{g} \frac{C^2}{3B^2} \psi'' \end{cases}$$

$$[11] \quad \alpha_1 = S_1 \cos rt + S'_1 \sin rt + \omega_1$$

$$[12] \quad \alpha_2 = S_2 \cos rt + S'_2 \sin rt + \omega_2$$

In these formulae :

$$m = \sqrt{\frac{g}{A} \cdot \frac{A^2}{2aa'} \frac{P}{p} \left[1 + \sqrt{1 - 4 \frac{aa'}{A^2} \frac{P}{p}} \right]} \# \sqrt{\frac{g}{A}} \cdot \sqrt{\frac{A^2}{aa'} \frac{P}{p}}$$

$$n = \sqrt{\frac{g}{A} \cdot \frac{A^2}{2aa'} \frac{P}{p} \left[1 - \sqrt{1 - 4 \frac{aa'}{A^2} \frac{P}{p}} \right]} \# \sqrt{\frac{g}{A}}$$

$$m' = \sqrt{\frac{g}{A} \cdot \frac{A^2}{2aa'} \frac{P}{p} \left[1 + \frac{a'}{A} \frac{p}{P} \left(\frac{3B^2}{C^2} - 1 \right) \right]} \left[1 + \sqrt{1 - 4 \frac{\frac{aa'}{A^2} \frac{p}{P} \frac{3B^2}{C^2}}{\left[1 + \frac{a'}{A} \frac{p}{P} \left(\frac{3B^2}{C^2} - 1 \right) \right]^2}} \right] \# \sqrt{\frac{g}{A}} \cdot \sqrt{\frac{A^2}{aa'} \frac{P}{p}} \# m$$

$$n' = \sqrt{\frac{g}{A} \cdot \frac{A^2}{2aa'} \frac{P}{p} \left[1 + \frac{a'}{A} \frac{p}{P} \left(\frac{3B^2}{C^2} - 1 \right) \right]} \left[1 - \sqrt{1 - 4 \frac{\frac{aa'}{A^2} \frac{p}{P} \frac{3B^2}{C^2}}{\left[1 + \frac{a'}{A} \frac{p}{P} \left(\frac{3B^2}{C^2} - 1 \right) \right]^2}} \right] \# \sqrt{\frac{g}{A}} \cdot \frac{B \sqrt{3}}{C}$$

$$r = \sqrt{\frac{g}{a'} \frac{P}{p}} \cdot \frac{b \sqrt{3}}{c}$$

SECOND PART

APPLICATION OF THE EQUATIONS OF MOTION TO THE CASE OF LINEAR TRACK OFFERING IDENTICAL DIFFERENCES OF LEVEL AT REGULAR INTERVALS

The track profile is defined by fig. 2; the vehicle passes over it at a speed V ; it is proposed to calculate the movements of the coach body after traversing k depressions, confining ourselves to determining X and α . As the detailed calculation is rather complicated only the principle will be outlined.

During the time intervals between instants 2 and 3, 4 and 5, 6 and 7, etc., when none of the wheels is over a depression the parameters $z_1 z_2 z_3 z_4$ all vanish, and in these intervals the functions φ and ψ are also zero.

It will be assumed that the vehicle suffers no vertical movement during the interval preceding instant 1. It then follows that

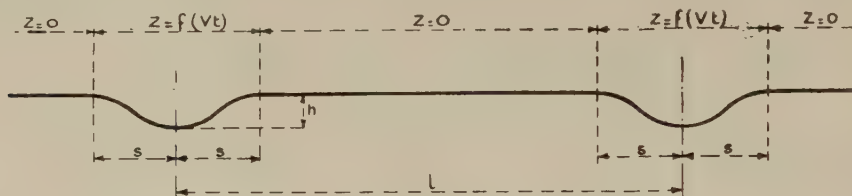


Fig. 2.

Starting with the fundamental equations [7] and [8], the first step is to evaluate φ and ψ which it will be remembered are particular solutions of equations [1] and [2].

It is convenient to consider several successive periods separated by the following instants:

- | | |
|---|--|
| instant 1: the 1st wheel pair enters the 1st depression | |
| » 2: the 1st » leaves the 1st » | |
| » 3: the 2nd » enters the 1st » | |
| » 4: the 2nd » leaves the 1st » | |
| » 5: the 3rd » enters the 1st » | |
| » 6: the 3rd » leaves the 1st » | |
| » 7: the 4th » enters the 1st » | |
| » 8: the 4th » leaves the 1st » | |
| » 9: the 1st » enters the 2nd » etc. | |

During the time intervals separating instants 1 and 2, 3 and 4, 5 and 6, etc., when one wheel pair occupies one depression, the functions φ and ψ have values determined by the foregoing definitions. It can be shown that at the beginning and end of each interval they are of the same value though not of the same sign. The values of the said functions at instant 1 will be designated φ_0 and ψ_0 .

at instant 1, $x \propto x_1 \dot{x}_2$ and their derivatives are zero.

During the time interval between instants 1 and 2, φ and ψ are not zero. By putting $X \propto x_1$ and x_2 and their derivatives equal to zero in the equations [7] [8] [9] [10] and their derivatives, we obtain eight equations which give the values of the eight constants D to R for the interval 1-2.

Knowing the values of these eight constants, we deduce the values of $X \propto x_1 x_2$ and their derivatives at instant 2. During the period 2-3 φ and ψ become zero. By writing into equations [7] [8] [9] [10] and their derivatives at instant 2 (considered as the commencement of period 2-3) the same values as those just found for the end of period 1-2, we obtain eight more equations giving values of the eight constants D-R for the period 2-3, and so on.

In the course of the calculations all the coefficients D to R, relating to intermediate time intervals, are eliminated. Those that remain refer only to the last interval, that is to say after the vehicle has passed over k depressions.

And finally :

$$X = \frac{8}{m^2 - n^2} \cdot \left\{ \begin{aligned} & - \frac{\sin m \frac{kl}{2V}}{\sin m \frac{l}{2V}} \cdot \cos m \frac{d}{V} \cdot \cos m \frac{B}{V} \cdot \left[(n^2 \varphi_0 + \varphi''_0) \sin m \frac{s}{V} - \frac{n^2 \varphi'_0 + \varphi'''_0}{m} \cos m \frac{s}{V} \right] \\ & \cdot \sin n \left[t - \frac{2(B+d) + (k-1)l}{2V} \right] \\ & + \frac{\sin n \frac{kl}{2V}}{\sin n \frac{l}{2V}} \cdot \cos n \frac{d}{V} \cdot \cos n \frac{B}{V} \cdot \left[(m^2 \varphi_0 + \varphi''_0) \sin n \frac{s}{V} - \frac{m^2 \varphi'_0 + \varphi'''_0}{n} \cos n \frac{s}{V} \right] \\ & \cdot \sin m \left[t - \frac{2(B+d) + (k-1)l}{2V} \right] \end{aligned} \right.$$

[13]

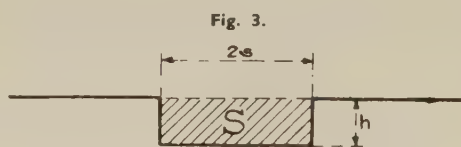
$$B \propto \frac{8}{m'^2 - n'^2} \cdot \left\{ \begin{aligned} & - \frac{\sin m' \frac{kl}{2V}}{\sin m' \frac{l}{2V}} \cdot \cos m' \frac{d}{V} \cdot \sin m' \frac{B}{V} \cdot \left[(n'^2 \psi_0 + \psi''_0) \sin m' \frac{s}{V} - \frac{n'^2 \psi'_0 + \psi'''_0}{m'} \cos m' \frac{s}{V} \right] \\ & \cdot \cos m' \left[t - \frac{2(B+d) + (k-1)l}{2V} \right] \\ & + \frac{\sin n' \frac{kl}{2V}}{\sin n' \frac{l}{2V}} \cdot \cos n' \frac{d}{V} \cdot \sin n' \frac{B}{V} \cdot \left[(m'^2 \psi_0 + \psi''_0) \sin n' \frac{s}{V} - \frac{m'^2 \psi'_0 + \psi'''_0}{n'} \cos n' \frac{s}{V} \right] \\ & \cdot \cos n' \left[t - \frac{2(B+d) + (k-1)l}{2V} \right] \end{aligned} \right.$$

These two equations completely solve the problem. It will be noted that they contain terms depending upon φ and ψ , that is upon z_1, z_2, z_3 and z_4 i.e. upon the profile of the track or, if preferred, the form of the depressions, as well as upon the speed V .

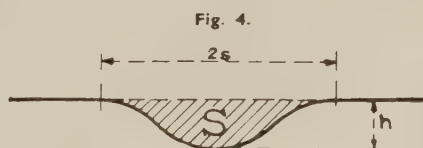
In the examples which follow, we shall study the influence of the form of the depressions upon that contain φ and ψ .

For the first example suppose that the curve $z = f(t)$ is a straight line; then $z = -h$ (fig. 3). In this case if we put :

$$\lambda = 2(B+d) + (k-1)l$$



$$Z = -h$$



$$Z = -\frac{h}{2} \left(1 - \cos \pi \frac{Vt}{s} \right)$$

the equations [13] become :

$$\begin{aligned}
 & \left. \begin{aligned} X &= \frac{2h}{m^2 - n^2} \cdot \left\{ \begin{aligned} & + n^2 \cdot \sin m \frac{s}{V} \cdot \frac{\sin m \frac{kl}{2V}}{\sin m \frac{2V}{l}} \cdot \cos m \frac{d}{V} \cdot \cos m \frac{B}{V} \cdot \sin m \left(t - \frac{\lambda}{2V} \right) \\ & - m^2 \cdot \sin n \frac{s}{V} \cdot \frac{\sin n \frac{kl}{2V}}{\sin n \frac{2V}{l}} \cdot \cos n \frac{d}{V} \cdot \cos n \frac{B}{V} \cdot \sin n \left(t - \frac{\lambda}{2V} \right) \end{aligned} \right. \\
 & [14] \\
 & \left. \begin{aligned} B \propto & \frac{2h}{m'^2 - n'^2} \cdot \left\{ \begin{aligned} & - n'^2 \cdot \sin m' \frac{s}{V} \cdot \frac{\sin m' \frac{kl}{2V}}{\sin m' \frac{2V}{l}} \cdot \cos m' \frac{d}{V} \cdot \sin m' \frac{B}{V} \cdot \cos m' \left(t - \frac{\lambda}{2V} \right) \\ & + m'^2 \cdot \sin n' \frac{s}{V} \cdot \frac{\sin n' \frac{kl}{2V}}{\sin n' \frac{2V}{l}} \cdot \cos n' \frac{d}{V} \cdot \sin n' \frac{B}{V} \cdot \cos n' \left(t - \frac{\lambda}{2V} \right) \end{aligned} \right.
 \end{aligned}
 \right\}
 \end{aligned}$$

In the second example (fig. 4) we assume the curve $z = f(t)$ to be sinusoidal :

$$z = \frac{h}{2} \left(\cos \pi \frac{V}{s} t - 1 \right)$$

In this case equations [13] become :

$$\begin{aligned}
 & \left. \begin{aligned} X &= \frac{h}{m^2 - n^2} \cdot \left\{ \begin{aligned} & + n^2 \cdot \frac{\sin m \frac{s}{V}}{1 - \left(\frac{ms}{\pi V} \right)^2} \cdot \frac{\sin m \frac{kl}{2V}}{\sin m \frac{2V}{l}} \cdot \cos m \frac{d}{V} \cdot \cos m \frac{B}{V} \cdot \sin m \left(t - \frac{\lambda}{2V} \right) \\ & - m^2 \cdot \frac{\sin n \frac{s}{V}}{1 - \left(\frac{ns}{\pi V} \right)^2} \cdot \frac{\sin n \frac{kl}{2V}}{\sin n \frac{2V}{l}} \cdot \cos n \frac{d}{V} \cdot \cos n \frac{B}{V} \cdot \sin n \left(t - \frac{\lambda}{2V} \right) \end{aligned} \right. \\
 & [15] \\
 & \left. \begin{aligned} B \propto & \frac{h}{m'^2 - n'^2} \cdot \left\{ \begin{aligned} & - n'^2 \cdot \frac{\sin m' \frac{s}{V}}{1 - \left(\frac{m's}{\pi V} \right)^2} \cdot \frac{\sin m' \frac{kl}{2V}}{\sin m' \frac{2V}{l}} \cdot \cos m' \frac{d}{V} \cdot \sin m' \frac{B}{V} \cdot \cos m' \left(t - \frac{\lambda}{2V} \right) \\ & + m'^2 \cdot \frac{\sin n' \frac{s}{V}}{1 - \left(\frac{n's}{\pi V} \right)^2} \cdot \frac{\sin n' \frac{kl}{2V}}{\sin n' \frac{2V}{l}} \cdot \cos n' \frac{d}{V} \cdot \sin n' \frac{B}{V} \cdot \cos n' \left(t - \frac{\lambda}{2V} \right) \end{aligned} \right.
 \end{aligned}
 \right\}
 \end{aligned}$$

In these two examples, when the quantities $\frac{ms}{V} \cdot \frac{ns}{V} \cdot \frac{m's}{V} \cdot \frac{n's}{V}$ are small, X and $B\alpha$ tend towards the following values :

$$[16] \quad X = \frac{mn}{m^2 - n^2} \cdot \frac{S}{V} \cdot \left\{ \begin{array}{l} + n \cdot \frac{\sin m \frac{kl}{2V}}{\sin m \frac{kl}{2V}} \cdot \cos m \frac{d}{V} \cdot \cos m \frac{B}{V} \cdot \sin m \left(t - \frac{\lambda}{2V} \right) \\ - m \cdot \frac{\sin n \frac{kl}{2V}}{\sin n \frac{kl}{2V}} \cdot \cos n \frac{d}{V} \cdot \cos n \frac{B}{V} \cdot \sin n \left(t - \frac{\lambda}{2V} \right) \end{array} \right.$$

$$B\alpha = \frac{m'n'}{m'^2 - n'^2} \cdot \frac{S}{V} \cdot \left\{ \begin{array}{l} - n' \cdot \frac{\sin m' \frac{kl}{2V}}{\sin m' \frac{kl}{2V}} \cdot \cos m' \frac{d}{V} \cdot \sin m' \frac{B}{V} \cdot \cos m' \left(t - \frac{\lambda}{2V} \right) \\ + m' \cdot \frac{\sin n' \frac{kl}{2V}}{\sin n' \frac{kl}{2V}} \cdot \cos n' \frac{d}{V} \cdot \sin n' \frac{B}{V} \cdot \cos n' \left(t - \frac{\lambda}{2V} \right) \end{array} \right.$$

In these formulae S represents the area outlined by the profile of one depression : $2hs$ in the first example and hs in the second.

It will be noted that this formula can be further simplified since, in practice, $m = m'$ and n^2 and n'^2 are negligible in relation to m^2 . This leads to the following approximation:

$$[17] \quad X = \frac{S}{V} \cdot \left\{ \begin{array}{l} + \frac{n^2}{m} \cdot \frac{\sin m \frac{kl}{2V}}{\sin m \frac{kl}{2V}} \cdot \cos m \frac{d}{V} \cdot \cos m \frac{B}{V} \cdot \sin m \left(t - \frac{\lambda}{2V} \right) \\ - n \cdot \frac{\sin n \frac{kl}{2V}}{\sin n \frac{kl}{2V}} \cdot \cos n \frac{d}{V} \cdot \cos n \frac{B}{V} \cdot \sin n \left(t - \frac{\lambda}{2V} \right) \end{array} \right.$$

$$B\alpha = \frac{S}{V} \cdot \left\{ \begin{array}{l} - \frac{n'^2}{m} \cdot \frac{\sin m \frac{kl}{2V}}{\sin m \frac{kl}{2V}} \cdot \cos m \frac{d}{V} \cdot \sin m \frac{B}{V} \cdot \cos m \left(t - \frac{\lambda}{2V} \right) \\ + n' \cdot \frac{\sin n' \frac{kl}{2V}}{\sin n' \frac{kl}{2V}} \cdot \cos n' \frac{d}{V} \cdot \sin n' \frac{B}{V} \cdot \cos n' \left(t - \frac{\lambda}{2V} \right) \end{array} \right.$$

The acceleration due to these displacements is :

$$[18] \quad \begin{aligned} X'' &= \frac{S}{V} \cdot \begin{cases} - m n^2 & \cdot \text{same factors as above, in } m \\ + n^3 & \cdot \text{same factors as above, in } n \end{cases} \\ B\alpha'' &= \frac{S}{V} \cdot \begin{cases} + m n'^2 & \cdot \text{same factors as above, in } m' (=m) \\ - n'^3 & \cdot \text{same factors as above, in } n' \end{cases} \end{aligned}$$

THIRD PART

DISCUSSION OF THE EQUATIONS OF MOTION

First of all, it will be observed that the coefficients m and m' defined above are virtually equal. It can be shown that they correspond to the period of motion of the bogie if, with the coach body fixed, it were set in vertical oscillation under the action of its own weight and of the two groups of springs.

The general equations [7] to [12] lead to the conclusions set out below (see also fig. 5):

1° That the body of the vehicle is set in motion by the resultant of the following components :

- vertical oscillation of the body itself (movement n);
- pitching of the body (movement n');
- vertical oscillation of the bogies alone (movement m);
- movement due to the track.

Movement m is the same as the corresponding one for the bogies but much attenuated, in the relationship :

$$\frac{1}{\frac{a}{g} m^2 - 1} \# \frac{1}{\frac{a}{g} \frac{g}{A} \frac{A^2}{aa'} \frac{P}{p} - 1} = \frac{1}{\frac{AP}{a'p} - 1}$$

or

$$\frac{1}{\frac{a}{g} \frac{C^2}{3B^2} m^2 - 1} \# \frac{1}{\frac{AP}{a'p} \frac{C^2}{3B^2} - 1}$$

2° That the bogies are set in motion by the resultant of components as follows :

- vertical oscillation due to the corresponding oscillation of the coach body;

— vertical oscillation due to the pitching of the body.

These two movements, n and n' , are the same as the corresponding ones for the body, but much attenuated in the relationship :

$$1 - \frac{a}{g} n^2 \text{ or } 1 - \frac{a}{g} \frac{C^2}{3B^2} n'^2 = \frac{a'}{A}$$

— vertical oscillation of the bogies alone (movement m);

— pitching of the bogies alone (movement r);

— movement due to the track.

Discussion of the problem takes the form of a study of the influence of the various parameters upon the nature of the motion and, by extension, upon its different components.

BOGIE MOVEMENTS

As we have just seen, the vertical motion of the bogies is determined by the same components as that of the body, modified by the appropriate co-efficient.

The conclusions reached regarding the movements of the body will therefore be valid for the vertical movements of the bogie, subject to the necessary choice of coefficient.

* * *

The pitching movement of the bogies is defined by equations [11] and [12]. It is an oscillatory movement of frequency :

$$\frac{r}{2\pi} = \frac{1}{2\pi} \sqrt{\frac{g}{a'p} \frac{P}{3b^2 c^2}}$$

MOTION	FREQUENCY	Effect upon vehicle	
		coach body	bogies
Vertical oscillations of body.	$\frac{n}{2\pi}$ where $n \neq \sqrt{\frac{g}{A}}$	full	lessened
Pitching of body	$\frac{n'}{2\pi}$ where $n \neq \sqrt{\frac{g}{A} \cdot \frac{B\sqrt{3}}{C}}$	full	lessened
Vertical oscillations of bogies.	$\frac{m}{2\pi}$ where $m \neq \sqrt{\frac{g}{A} \cdot \frac{A^2 P}{a a' p}}$	lessened	full
Pitching of bogies	$\frac{r}{2\pi}$ where $r = \sqrt{\frac{g}{a' p} \cdot \frac{b\sqrt{3}}{c}}$	nil	full
Influence of track		full	full

Fig. 5. — Components of vehicle movements.

A calculation similar to that made for $B\alpha$ would show that after traversing k depressions the pitching of the bogies (α_1 or α_2) is defined by an equation of the form.

$$d\alpha_1 = \frac{1}{r} \cdot \sin r \frac{d}{V} \cdot \frac{\sin r \frac{kl}{2V}}{\sin r \frac{l}{2V}} \dots \dots$$

The amplitude of motion grows smaller as r or d grow larger; that is to say, when P , b or d are increased or when a' , p or c are diminished.

It is therefore advantageous to have a light bogie (p small) with a long wheelbase (d large) and the helical springs spaced well apart (dimension b).

The above formula shows the existence of critical speeds cancelling out the term

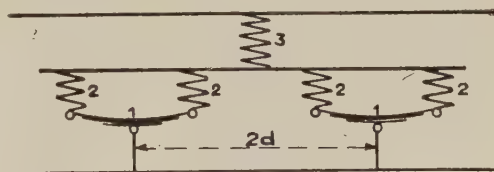
$$\sin r \frac{l}{2V}$$

At these speeds, which correspond to the formula :

$$V = \frac{rl}{2k'\pi}, \text{ the factor } \frac{\sin r \frac{kl}{2V}}{\sin r \frac{l}{2V}}$$

reaches its maximum value k and the angle of pitching α_1 reaches its maximum also.

This explains the vibration, at certain speeds, of brake rigging that is without guides and rests upon the bogie cross stays. It also explains the wear of axleboxes and guides. These undesirable features were less troublesome in the former bogie designs with three stages of springs (fig. 6) since the coefficient b was then almost twice as large as with the present bogies, which had the effect of halving the pitching movement of the bogies.



1. Bearing spring.
2. Helical spring.
3. Elliptical spring between bogie bolster and coach body.
Fig. 6. — Diagram of former type of bogie.

COACH BODY MOVEMENTS

1° Preliminary observations.

The three oscillatory movements of the body, m , n and n' are quite distinct from

one another; n and n' are of practically the same order, but m is five or six times as great. The equations under [17] show that as a result of this the amplitude of movements n and n' is five or six times greater than that of m .

On the other hand equation [18] shows that the acceleration of movement m is five or six times greater than that of n and n' .

It follows that all three movements are of virtually the same importance in their effect upon the riding qualities of the vehicle.

In discussing these qualities we shall make use of the equations under [15] or their simplified forms [16] or [17] which more nearly represent the practical case.

2° Relevant parameters.

Equations [1] and [2] divide the parameters into two groups :

— those appearing on the L.H. side of the equations, namely

$$a, a', A, \frac{p}{P}, B, C ;$$

which may be grouped thus :

$$A, \frac{A^2}{a a'} \cdot \frac{P}{p}, B, C.$$

These four are the only ones that determine the coefficients m n and n' .

— those on the R.H. side namely, terms in z which after integration yield terms containing V, l, S, d .

The most important conclusion drawn here is that two vehicles of identical dimensions but different weights, running at the same speed on the same track, will ride in identically the same manner provided that they share the same values for the parameters :

$$A \text{ and } \frac{A'}{a a'} \cdot \frac{P}{p}.$$

3° Influence of S (profile of depressions).

Equations [14] or [17] and [18] show that the acceleration and the amplitude of motion are proportional to the area S outlined by the profile of each depression.

It follows that the effects of two geometrically similar depressions are proportional to the squares of their respective depths.

4° Influence of l (length of rails).

The general equations under [13] show that so far as movement m is concerned the coefficient

$$\frac{\sin m \frac{kl}{2V}}{\sin m \frac{l}{2V}}$$

has its maximum value when

$$\sin m \frac{l}{2V} = 0, \text{ that is to say when } \frac{ml}{2V} = k'\pi,$$

$$\text{or } V = \frac{ml}{2k'\pi}.$$

This formula reveals the existence of a series of critical speeds; but it is evident that the speeds so determined are lowest when k' is greatest. In effect, k' represents the number of bogie oscillations during the interval between passing two rail joints. The higher the figure k' , the greater is the damping of movement m .

For normal values of m and l , and when $k' = 1$, the values of V lie well beyond the usual speed range. When $k' = 2$, V is 138 km/h for $l = 12$ metres, when $k' = 3$, $V = 92$ km/h for $l = 12$ m and 138 km/h for $l = 18$ metres.

It appears that where movement m is concerned an 18 metre rail is better than one of 12 metres. Factually, 138 km/h is a critical speed for $l = 12$ m and $k' = 2$,

and also for $l = 18$ metres (but with $k' = 3$ it matters less); 92 km/h is critical only for $l = 12$ metres.

* * *

However, the coefficient l is much more important in regard to movements n and n' than it is for m . The critical speeds are determined by the formulae :

$$\sin n \frac{l}{2V} = \text{and } 0 \sin n' \frac{l}{2V} = 0$$

that is to say :

$$V = \frac{nl}{2k'\pi} \text{ and } V = \frac{n'l}{2k'\pi}.$$

For normal values of n and n' and for $l = 18$ metres, V becomes 72 km/h

$$\left(\text{and } \frac{72}{2}, \frac{72}{3}, \frac{72}{4}, \text{ etc.} \right)$$

$$\text{and } V = 82 \text{ km/h } \left(\text{and } \frac{82}{2}, \frac{82}{3}, \text{ etc.} \right).$$

These critical speeds are of great importance because they mean that the factors

$$\frac{\sin n \frac{kl}{2V}}{\sin n \frac{l}{2V}} \text{ or } \frac{\sin n' \frac{kl}{2V}}{\sin n' \frac{l}{2V}}$$

reach their maximum value, equal to k .

Speeds calculated in this way will vary with the value of l , but it will be noted that the figures for an 18 metre rail fall just below the normal speeds. If l is increased, so are the critical speeds, but it is practicable to increase them so as to lie beyond the normal speeds which at present reach 140 km/h. In other words, if l is to be made longer than 18 metres it is worth while increasing it to 36 metres, avoiding the intermediate values.

5° Influence of m , n and n' (representing flexibility of springs) with B , C and d invariable.

On studying formulae [16] to [18], it will be observed that the amplitude and acceleration of the various components of

the motion increase in magnitude as m , n and n' increase (i.e. the stiffness of the springs). This follows from the presence in formula [17] of the terms : $\frac{n^2}{m}$, n , $\frac{n'^2}{m}$ and n' as primary factors, and of the terms mn^2 , n^3 , mn'^2 and n'^3 in formula [18].

From this standpoint, it should be of advantage to soften the suspension.

* * *

But these coefficients are also operative in terms containing functions of the *sine* or *cosine*, with expressions of the form :

$$\frac{ml}{V}, \frac{md}{V}, \frac{mB}{V}$$

(and others with n and n' in place of m).

The maximum values of the factors :

$$\cos \frac{md}{V}, \cos \frac{nd}{V}, \cos \frac{n'd}{V},$$

$$\cos \frac{mB}{V}, \sin \frac{mB}{V}, \cos \frac{nB}{V}, \sin \frac{n'B}{V},$$

together with the cancellation of the factors :

$$\sin \frac{ml}{2V}, \sin \frac{nl}{2V}, \sin \frac{n'l}{2V},$$

determine the maximum amplitudes and accelerations.

The cancellation of the same factors in

$$\frac{d}{V} \text{ and } \frac{B}{V}$$

determines on the other hand the zero amplitudes and accelerations.

From these observations the following conclusions may be drawn :

If we consider a given vehicle and a given track, V is the only variable factor. There exists a series of speeds V that are critical and favourable, depending on whether the above mentioned factors have their maximum or their null values.

Since all these factors contain the quantities :

$$\frac{m}{V}, \frac{n}{V} \text{ or } \frac{n'}{V},$$

it is possible to control the span of the critical and favourable speed range by controlling uniquely m , n and n' .

In consequence, if it is desired to increase V while maintaining its relative position in the range of critical and favourable speeds, then m , n and n' must be increased in the same proportion. This is the same as saying that *the suspension must be stiffened as the speed is increased*.

However, if this course is taken, it will be seen from the formulae under [17], which contain the factors :

$$\frac{1}{V}, \frac{n^2}{m}, \frac{1}{V}n, \frac{1}{V}, \frac{n'^2}{m}, \frac{1}{V}n',$$

that the amplitude of the movements remains the same if the following ratios are held constant :

$$\frac{m}{V}, \frac{n}{V} \text{ and } \frac{n'}{V}.$$

This is not the case for formulae [18] relating to the acceleration, which contain the factors :

$$\frac{mn^2}{V}, \frac{n^3}{V}, \frac{mn'^2}{V}, \frac{n'^3}{V},$$

and which give higher values when m , n and n' increase proportionally with V .

6° Influence of dimensions of vehicle (B , C , d) — the coefficients m , n and n' remaining invariable.

The same arguments as above show that the range of critical and favourable speeds may be widened at will by simultaneously varying the coefficients l , B and d .

Equations [17] and [18] show clearly that when V is increased and the coefficients m , n and n' remain fixed, the riding characteristics (amplitude, acceleration, relative position of V in the range of critical and favourable speeds) are maintained if B , d and l are increased in proportion to V .

7° Critical and favourable speed ranges.

The foregoing observations direct attention to a series of critical, unfavourable speeds.

It is admitted that, since the range of normal speeds has remained constant for many years, the most suitable values for the parameters m n n' B and d have been found by trial and error. This really means that these parameters place the critical speeds outside the normal range and the favourable ones within it.

In the event of an appreciable increase in the normal running speeds, what would be the most practicable steps to take to preserve the riding qualities of the vehicle?

The generally accepted view is that in order to preserve the characteristics of an oscillatory movement, it is the acceleration that must be held constant.

To this end, it will be clear, from equations [15] to [18] that it would suffice to maintain the values of the following ratios :

$$\frac{m}{V^{\frac{1}{3}}}, \frac{n}{V^{\frac{1}{3}}}, \frac{n'}{V^{\frac{1}{3}}}, \frac{l}{V^{\frac{2}{3}}}, \frac{d}{V^{\frac{2}{3}}}, \frac{B}{V^{\frac{2}{3}}};$$

this simultaneous increase in the stiffness of the suspension together with size of vehicle and length of rail has the effect of reducing the amplitude of motion, maintaining the maximum acceleration, and holding the normal speed in position relative to the complete range of critical and favourable speeds.

It is not practicable however, to vary l , B and d , and this being so it is necessary to aim at constant ratios for the following :

$$\frac{m}{V}, \frac{n}{V} \text{ and } \frac{n'}{V};$$

the result of increasing m , n and n' is to maintain the amplitude of motion but to increase the acceleration, but this undesirable feature is offset by the fact that the normal speeds retain their favourable position within the series of critical and favourable speeds.

It is true that the values customarily chosen for m , n and n' are not necessarily the best that could be found. The foregoing analysis permits the calculation, for any given vehicle, of the coefficients m , n and n' so as to ensure that the favourable speeds shall coincide with the normal range while the critical ones lie beyond it.

8° Resonance of the various components of motion.

In order to avoid resonance, care should be taken to avoid a simple ratio between the coefficients m , n and n' , taken in pairs.

Consequently :

$$\frac{m}{n} = \sqrt{\frac{A^2 P}{aa' p}}$$

must not be a whole number,

$$\frac{m}{n'} = \sqrt{\frac{A^2 P}{aa' p}} \cdot \frac{C}{B\sqrt{3}}$$

must not be a whole number, and

$$\frac{n'}{n} = \frac{B\sqrt{3}}{C}$$

must not be a simple ratio.

9° Motion of any given point in the vehicle.

The vertical movement of a point in the vehicle situated at a distance Y from the centre of gravity (measured on the longitudinal axis) is determined by the equation :

$$\xi = X + Y \cdot \alpha = X + B\alpha \cdot \frac{Y}{B}$$

The movement n (which does not appear in the equation giving $B\alpha$) is independent of Y .

The movement n' does appear in the equation for $B\alpha$ and is governed by the coefficient $\frac{Y}{B}$. This movement therefore becomes increasingly important with increasing distance from the centre of gravity.

Movement m which appears both in the formula for X and that for $B\alpha$ comprises the following components derived from formulae [17]:

$$\frac{S}{V} \cdot \frac{1}{m} \cdot \frac{\sin m \frac{kl}{2V}}{\sin m \frac{l}{2V}} \cdot \cos m \frac{d}{V} \cdot \left\{ \begin{array}{l} + n^2 \cos m \frac{B}{V} \cdot \sin m \left(t - \frac{\lambda}{2V} \right) \\ - \frac{Y}{B} n'^2 \cdot \sin m \frac{B}{V} \cdot \cos m \left(t - \frac{\lambda}{2V} \right) \end{array} \right\}$$

The terms between $\{ \}$ are written as follows :

$$\sqrt{\cos^2 m \frac{B}{V} + \left(\frac{3BY}{C^2} \right)^2 \sin^2 m \frac{B}{V}} \cdot \sin m \left(t - \frac{\lambda}{2V} - \dots \right)$$

If $\frac{3BY}{C^2}$ is < 1 , the maximum value of the quantity under the root sign is unity (for certain values of V) whatever the value of Y .

If $\frac{3BY}{C^2}$ is > 1 the maximum for the quantity under the root sign is $\frac{3BY}{C^2}$ (for certain values of V).

Consequently, the maximum possible amplitude of motion m remains the same so long as $Y < \frac{C^2}{3B^2}$;

and it increases in proportion to Y , when Y exceeds $\frac{C^2}{3B^2}$.

Summarizing, the motion n is the same throughout the length of the vehicle, but motions n' and m are increasingly accentuated towards the extremities.

FOURTH PART

DAMPING ACTION OF THE SPRINGS

So far as we have gone, it has been assumed that there is no inherent damping in the springs and no internal friction.

It is now proposed to study the influence of damping upon the results obtained.

It will be assumed that the springs have no internal friction (i.e. helical springs) and are fitted with dampers that deaden the oscillations in accordance with the law of proportionality to speed of displacement; it is also assumed that the damping is inversely proportional to the flexibility of the springs.

It was found for example that the reaction offered by the spring l_1 is proportional to its loss of height:

$$f_1 = \frac{P}{4a'} \left(a' - x_1 + b\alpha_1 + z_1 \frac{d+b}{2d} + z_2 \frac{d-b}{2d} \right)$$

The force exerted by the corresponding damper will be proportional to the speed of deflection:

$$f'_1 = \mu \frac{P}{4a'} \left(-x'_1 + b\alpha'_1 + z'_1 \frac{d+b}{2d} + z'_2 \frac{d-b}{2d} \right)$$

where the expression on the R.H. side is derived from the R.H. side of the preceding equation.

Finally, it will be supposed that the coefficient μ is the same for all the springs.

* * *

The equations for this problem are set up in the same way as in the First Part, and lead to the following expressions:

$$\begin{aligned} \frac{p}{g} x''_1 + \frac{AP - a'p}{aa'} (\mu x'_1 + x_1) - \frac{P - p}{a} (\mu X' + X) \\ + \frac{P - p}{a} (\mu B\alpha' + B\alpha) = \frac{P}{a'} \left(\mu \frac{z'_1 + z'_2}{2} + \frac{z_1 + z_2}{2} \right) \end{aligned}$$

$$\begin{aligned} \frac{p}{g} x''_2 + \frac{AP - a'p}{aa'} (\mu x'_2 + x_2) - \frac{P - p}{a} (\mu X' + X) \\ - \frac{P - p}{a} (\mu B\alpha' + B\alpha) = \frac{P}{a'} \left(\mu \frac{z'_3 + z'_4}{2} + \frac{z_3 + z_4}{2} \right) \end{aligned}$$

$$\frac{p}{g} \alpha''_1 + \frac{P}{a'} \frac{b^2}{c^2} (\mu \alpha'_1 + \alpha_1) = - \frac{P}{a'} \frac{b^2}{c^2} \left(\mu \frac{z'_1 - z'_2}{2} + \frac{z_1 - z_2}{2} \right)$$

$$\frac{p}{3g} \alpha''_2 + \frac{P}{a'} \frac{b^2}{c^2} (\mu \alpha'_2 + \alpha_2) = - \frac{P}{a'} \frac{b^2}{c^2} \left(\mu \frac{z'_3 - z'_4}{2} + \frac{z_3 - z_4}{2} \right)$$

$$\frac{a}{g} X'' + \mu X' + X = \mu \frac{x'_1 + x'_2}{2} + \frac{x_1 + x_2}{2}$$

$$\frac{a}{g} \frac{C^2}{3B^2} B\alpha'' + \mu B\alpha' + B\alpha = - \mu \frac{x'_1 - x'_2}{2} - \frac{x_1 - x_2}{2}$$

The first step in solving the foregoing is to separate the variables, which gives the following equations analogous to equations [1] to [4]. (Equations giving the less important variables α_1 and α_2 will be ignored, as will also those relating to x_1 and x_2).

$$[19] \quad \frac{aa'}{g^2} \frac{p}{P} X'''' + \mu \frac{A}{g} X''' + \left(\mu^2 + \frac{A}{g} \right) X'' + 2\mu X' + X = \mu^2 \frac{z''_1 + z''_2 + z''_3 + z''_4}{4} \\ + 2\mu \frac{z'_1 + z'_2 + z'_3 + z'_4}{4} + \frac{z_1 + z_2 + z_3 + z_4}{4}$$

$$[20] \quad \frac{aa'}{g^2} \frac{p}{P} \frac{C^2}{3B^2} B\alpha'''' + \mu \frac{A'}{g} \frac{C^2}{3B^2} B\alpha''' + \left(\mu^2 + \frac{A'}{g} \frac{C^2}{3B^2} \right) B\alpha'' + 2\mu B\alpha' + B\alpha = \\ - \mu^2 \frac{z''_1 + z''_2 - z''_3 - z''_4}{4} - 2\mu \frac{z'_1 + z'_2 - z'_3 - z'_4}{4} - \frac{z_1 + z_2 - z_3 - z_4}{4}$$

$$[21] \quad \frac{x_1 + x_2}{2} = -\mu \frac{a}{g} X''' - \left(\mu^2 \frac{AP}{a'p} - \frac{a}{g} \right) X'' - \mu^3 \frac{g}{a'} \frac{P}{p} X' \\ - \left(\mu^2 \frac{g}{a'} \frac{P}{p} - 1 \right) X + \mu^2 \frac{g}{a'} \frac{P}{p} \left(\mu \frac{z'_1 + z'_2 + z'_3 + z'_4}{4} + \frac{z_1 + z_2 + z_3 + z_4}{4} \right)$$

$$[22] \quad \frac{x_1 - x_2}{2} = \mu \frac{a}{g} \frac{C^2}{3B^2} B\alpha''' + \left(\mu^2 \frac{A'P}{a'p} - \frac{a}{g} \right) B\alpha'' + \mu^3 \frac{g}{a'} \frac{P}{p} B\alpha' \\ + \left(\mu^2 \frac{g}{a'} \frac{P}{p} - 1 \right) B\alpha + \mu^2 \frac{g}{a'} \frac{P}{p} \left(\mu \frac{z'_1 + z'_2 - z'_3 - z'_4}{4} + \frac{z_1 + z_2 - z_3 - z_4}{4} \right)$$

$$\text{where } A' = A + \frac{a'p}{P} \left(\frac{3}{C^2} B^2 - 1 \right)$$

[19] and [20] are differential equations of the fourth order; but the expressions on the L.H. side may be written as the product of two factors of the second degree and their four solutions may thus be obtained.

Putting :

$$\theta_1 = \frac{\mu}{\frac{A}{g} \left(1 - \sqrt{1 - 4 \frac{aa'}{A^2} \frac{p}{P}} \right)}$$

$$\theta_3 = \frac{\mu}{\frac{A'}{g} \frac{C^2}{3B^2} \left(1 - \sqrt{1 - 4 \frac{aa'}{A'^2} \frac{p}{P} \frac{3B^2}{C^2}} \right)}$$

$$\theta_4 = \frac{\mu}{\frac{A'}{g} \frac{C^2}{3B^2} \left(1 + \sqrt{1 - 4 \frac{aa'}{A'^2} \frac{p}{P} \frac{3B^2}{C^2}} \right)}$$

$$\theta_2 = \frac{\mu}{\frac{A}{g} \left(1 + \sqrt{1 - 4 \frac{aa'}{A^2} \frac{p}{P}} \right)}$$

$$m_1^2 = m^2 - \theta_1^2 \quad n_1^2 = n^2 - \theta_2^2 \\ m_1'^2 = m'^2 - \theta_3^2 \quad n_1'^2 = n'^2 - \theta_4^2$$

the solutions of the characteristic equation of equation [19] are: $-\theta_1 \pm m_1 i$ and $-\theta_2 \pm n_1 i$; the solutions for [20] are: $-\theta_3 \pm m_1' i$ and $-\theta_4 \pm n_1' i$.

The values of X and $B\alpha$ become :

$$[23] \quad X = e^{-\theta_1 t} (D \cos m_1 t + E \sin m_1 t) + e^{-\theta_2 t} (F \cos n_1 t + G \sin n_1 t) + \varphi$$

$$[24] \quad B\alpha = e^{-\theta_3 t} (L \cos m_1' t + M \sin m_1' t) + e^{-\theta_4 t} (N \cos n_1' t + R \sin n_1' t) + \psi$$

where φ and ψ are particular solutions of equations [19] and [20].

These equations may be compared with [7] and [8] in the First Part.

* * *

The case for passage over k depressions is dealt with as in the Second Part, and leads to the following general equations [25] where $\Phi_1 \Phi_2 \Psi_1 \Psi_2$ are complex functions of φ and ψ .

These equations are comparable with [13].

$$[25] \quad X = \frac{4 \frac{g}{a}}{m^2 - n^2} \cdot \left\{ \begin{aligned} &+ e^{-\theta_1} \left(t - \frac{\frac{k-1}{2} l + B + d}{V} \right) \cdot \sqrt{\frac{sh^2 \theta_1 \frac{kl}{2V} + \sin^2 m_1 \frac{kl}{2V}}{sh^2 \theta_1 \frac{l}{2V} + \sin^2 m_1 \frac{l}{2V}}} \\ &\quad \cdot \sqrt{sh^2 \theta_1 \frac{B}{V} + \cos^2 m_1 \frac{B}{V}} \cdot \sqrt{sh^2 \theta_1 \frac{d}{V} + \cos^2 m_1 \frac{d}{V}} \\ &\quad \cdot \Phi_1 \cdot \cos m_1 (t - \Lambda) \\ &+ e^{-\theta_2} \left(t - \frac{\frac{k-1}{2} l + B + d}{V} \right) \cdot \sqrt{\frac{sh^2 \theta_2 \frac{kl}{2V} + \sin^2 n_1 \frac{kl}{2V}}{sh^2 \theta_2 \frac{l}{2V} + \sin^2 n_1 \frac{l}{2V}}} \\ &\quad \cdot \sqrt{sh^2 \theta_2 \frac{B}{V} + \cos^2 n_1 \frac{B}{V}} \cdot \sqrt{sh^2 \theta_2 \frac{d}{V} + \cos^2 n_1 \frac{d}{V}} \\ &\quad \cdot \Phi_2 \cdot \cos n_1 (t - \Lambda) \end{aligned} \right.$$

$$B\alpha = \frac{4\frac{g}{a} \cdot \frac{3B^2}{C^2}}{m'^2 - n'^2} \cdot \left\{ \begin{aligned} &+ e^{-\theta_3} \left(t - \frac{\frac{k-1}{2}l + B + d}{V} \right) \cdot \sqrt{\frac{sh^2\theta_3 \frac{kl}{2V} + \sin^2 m'_1 \frac{kl}{2V}}{sh^2\theta_3 \frac{l}{2V} + \sin^2 m'_1 \frac{l}{2V}}} \\ &\quad \cdot \sqrt{\frac{sh^2\theta_3 \frac{B}{V} + \sin^2 m'_1 \frac{B}{V}}{sh^2\theta_3 \frac{d}{V} + \cos^2 m'_1 \frac{d}{V}}} \cdot \Psi_1 \cdot \cos m'_1 (t - \Lambda') \\ &+ e^{-\theta_4} \left(t - \frac{\frac{k-1}{2}l + B + d}{V} \right) \cdot \sqrt{\frac{sh^2\theta_4 \frac{kl}{2V} + \sin^2 n'_1 \frac{kl}{2V}}{sh^2\theta_4 \frac{l}{2V} + \sin^2 n'_1 \frac{l}{2V}}} \\ &\quad \cdot \sqrt{\frac{sh^2\theta_4 \frac{B}{V} + \sin^2 n'_1 \frac{B}{V}}{sh^2\theta_4 \frac{d}{V} + \cos^2 n'_1 \frac{d}{V}}} \cdot \Psi_2 \cdot \cos n'_1 (t - \Lambda') \end{aligned} \right.$$

* * *

Finally, considering the case of the first example in Part II (that of a rectangular depression of side — h and length $2s$), we obtain the equations in [26] below. To simplify their presentation, the starting point in time $T = 0$ has been chosen as the instant at which the fourth wheel pair has just crossed the k^{th} depression :

$$t = T + \frac{(k-1)l + 2B + 2d + 2s}{V};$$

In addition, the following symbols are employed :

$$\begin{aligned} \boxed{\theta_1 \cos m_1 x} &= e^{-\theta_1 x} \cdot \sqrt{sh^2 \theta_1 x + \cos^2 m_1 x} \\ \boxed{\theta_1 \sin m_1 x} &= e^{-\theta_1 x} \cdot \sqrt{sh^2 \theta_1 x + \sin^2 m_1 x} \end{aligned}$$

These equations may be compared with those under [14]; while the latter may be regarded as a particular case of equations [26] where μ has the value 0, which reduces $\theta_1 \theta_2 \theta_3 \theta_4$ to zero.

It is interesting to compare the characteristics of the damped and undamped motions.

The following points will be observed :

- the frequencies of the components proportional to m , n and n' become proportional to $m_1 n_1$ and n'_1 in the damped motion. In view of the relationship $m_1^2 = m^2 - \theta_1^2$, etc., these frequencies are progressively diminished as $\theta_1 \theta_2 \theta_3$ and θ_4 (that is, the damping force μ) increase in value.

— in the undamped motion, the terms containing $\cos m \frac{B}{V}$ (or the sine, or $n - n'$, or $d - s - l$) define the speed as critical or favourable, depending on whether they are equal to 1 or to zero.

The corresponding terms for damped motion take the form :

$$\left| \theta_1 \cos m_1 \frac{B}{V} \right| = e^{-\theta_1 \frac{B}{V}} \sqrt{sh^2 \theta_1 \frac{B}{V} + \cos^2 m_1 \frac{B}{V}}$$

It will be noted that :

$$e^{-\theta_1 \frac{B}{V}} \sqrt{sh^2 \theta_1 \frac{B}{V} + 0} < \left| \theta_1 \cos m_1 \frac{B}{V} \right| < e^{-\theta_1 \frac{B}{V}} \sqrt{sh^2 \theta_1 \frac{B}{V} + 1}$$

that is to say :

$$e^{-\theta_1 \frac{B}{V}} sh \theta_1 \frac{B}{V} < \left| \theta_1 \cos m_1 \frac{B}{V} \right| < e^{-\theta_1 \frac{B}{V}} sh \theta_1 \frac{B}{V}$$

or again :

$$\frac{1 - e^{-2\theta_1 \frac{B}{V}}}{2} < \left| \theta_1 \cos m_1 \frac{B}{V} \right| < \frac{1 + e^{-2\theta_1 \frac{B}{V}}}{2}$$

$$X = \frac{2h}{m^2 - n^2} \cdot \left\{ \begin{aligned} &+ n^2 \sqrt{1 + \frac{\theta_1^2}{m_1^2}} \cdot e^{-\theta_1 T} \cdot \left| \theta_1 \sin m_1 \frac{s}{V} \right| \cdot \frac{\left| \theta_1 \sin m_1 \frac{kl}{2V} \right|}{\left| \theta_1 \sin m_1 \frac{l}{2V} \right|} \\ &\cdot \left| \theta_1 \cos m_1 \frac{d}{V} \right| \cdot \left| \theta_1 \cos m_1 \frac{B}{V} \right| \cdot \cos m_1 (T - \Lambda) \\ &+ m^2 \sqrt{1 + \frac{\theta_2^2}{n_1^2}} \cdot e^{-\theta_2 T} \cdot \left| \theta_2 \sin n_1 \frac{s}{V} \right| \cdot \frac{\left| \theta_2 \sin n_1 \frac{kl}{2V} \right|}{\left| \theta_2 \sin n_1 \frac{l}{2V} \right|} \\ &\cdot \left| \theta_2 \cos n_1 \frac{d}{V} \right| \cdot \left| \theta_2 \cos n_1 \frac{B}{V} \right| \cdot \cos n_1 (T - \Lambda) \end{aligned} \right.$$

$$B\alpha = \frac{2h}{m'^2 - n'^2} \cdot \left\{ \begin{aligned} &+ n'^2 \sqrt{1 + \frac{\theta_3^2}{m'^2}} \cdot e^{-\theta_3 T} \cdot \boxed{\theta_3 \sin m'_1 \frac{s}{V}} \cdot \frac{\boxed{\theta_3 \sin m'_1 \frac{kl}{2V}}}{\boxed{\theta_3 \sin m'_1 \frac{l}{2V}}} \\ &\cdot \boxed{\theta_3 \cos m'_1 \frac{d}{V}} \cdot \boxed{\theta_3 \sin m'_1 \frac{B}{V}} \cdot \cos m'_1 (T - \Lambda') \\ &+ m'^2 \sqrt{1 + \frac{\theta_4^2}{n'^2}} \cdot e^{-\theta_4 T} \cdot \boxed{\theta_4 \sin n'_1 \frac{s}{V}} \cdot \frac{\boxed{\theta_4 \sin n'_1 \frac{kl}{2V}}}{\boxed{\theta_4 \sin n'_1 \frac{l}{2V}}} \\ &\cdot \boxed{\theta_4 \cos n'_1 \frac{d}{V}} \cdot \boxed{\theta_4 \sin n'_1 \frac{B}{V}} \cdot \cos n'_1 (T - \Lambda') \end{aligned} \right.$$

The term $e^{-2\theta_1 \frac{B}{V}}$ is always < 1 and approaches zero as the value of $\theta_1 \frac{B}{V}$ increases; consequently the term

$$\boxed{\theta_1 \cos m_1 \frac{B}{V}}$$

fluctuates between 0 and 1, without ever becoming equal to zero or to unity.

Thus, the terms of the form $\boxed{}$ determine, as in the case of undamped motion, the critical and the favourable speeds but these speeds are less critical and less favourable than for undamped motion;

— with special reference to terms of the form $\boxed{}$ containing $\frac{l}{2V}$: these have a numerator the value of which lies between:

$$\frac{1 - e^{-\theta_1 \frac{kl}{V}}}{2} \text{ and } \frac{1 + e^{-\theta_1 \frac{kl}{V}}}{2};$$

As k increases, these limits both approach $\frac{1}{2}$; and so the numerator in question approaches $\frac{1}{2}$; and since the denominator

of the fraction $\frac{\boxed{}}{\boxed{}}$ can never be zero, the fraction tends towards a finite value when k is indefinitely increased.

On the other hand, in undamped motion for certain values of V the corresponding term may reach a value k that may increase indefinitely;

— the various components of the motion are multiplied by a factor $e^{-\theta t}$ (which does not exist in the undamped motion) and their amplitude thus diminishes and may approach 0. This falling off is all the more rapid as θ , that is the damping force μ , increases.

This damping factor is of primary importance and considerably reduces the amplitude of the damped motion together with the influence of the critical and favourable speeds previously referred to:

— so far as concerns acceleration, it is easy to confirm that in equations [14] as

in equations [26] the acceleration follows the same form as the amplitude when each component is multiplied by $m^2 n^2 m'^2$ and n'^2 respectively.

Thus, the accelerations accompanying damped and undamped motion may be compared among themselves in the same way as the amplitudes.

— One final comment is appropriate : if the track offers a sharp depression Δh the springs compress by this amount and impart to the undamped movement and acceleration proportional to Δh ; the time Δt required to traverse the depression will not enter into the problem.

For a damped movement the compression of the springs imparts the same acceleration, proportional to Δh , as for an undamped one; but the dampers impart a complementary

acceleration, proportional to $\frac{\Delta h}{\Delta t}$; which increases with increasing damping force μ or diminishing time Δt . In other words, the shocks are felt more with damped movements than with undamped movements.

CONCLUSIONS

It will be appropriate at this stage of our investigation to review its findings.

Our calculations suffer from the disadvantage of all calculations : taking account only of those factors that may be written into an equation, they neglect all the indeterminate factors. In the present instance, the analysis has been confined to vertical movements. Rolling and hunting have been ignored. Among other things, it has been assumed that the springs deflect in proportion to the load, that the track is straight and that it is cut at regular intervals by identically similar rail joints.

It cannot be claimed that these hypotheses and restrictions offer a rigorous comparison with the practical case, nor can any other than a relative value be attached to the results obtained. Calculation does not enable us to dispense with experiment.

Nevertheless, they provide a consistent

explanation of the phenomena observed in practice; for the rest, we have voluntarily excluded all controversial theory from our hypotheses and have limited our conclusions to those capable of mathematical proof. For these reasons we feel that our calculations may be regarded with considerable confidence and that they may serve as a legitimate guide for experimental studies.

The number of parameters that may be varied in order to modify the riding characteristics of a coach is quite considerable and it would be out of the question to give to each one all its possible values in order to find, empirically, the optimum. By virtue of the foregoing study, it is certainly possible to limit trial and error and to foresee, for each parameter under consideration, the sense in which it is necessary to make it vary.

The essential conclusions that have emerged from the calculations are summarised below :

1. In addition to movements due to the track the body of a vehicle when running is acted upon by three sinusoidal motions : vertical oscillation of the centre of gravity (and of the whole of the superstructure) — pitching of the body itself — motion proper to the bogies and transmitted to the body. This last named is of smaller amplitude than the first two but of higher frequency and maximum acceleration; it is therefore equally as important in determining the riding qualities of the vehicle.

2. The coefficients A and $\frac{A^2 P}{aa' p}$ are of fundamental significance, for from them are calculated the frequencies, amplitudes and accelerations of the three sinusoidal motions described above.

3. For any given vehicle there exists a sequence of critical and favourable speeds. The foregoing analysis has shown how this sequence is influenced by the length of the rail and by the characteristics of the vehicle, notably by the suspension. It is clearly essential that the sequence of critical and favourable speeds should be correctly placed

in relation to the running speeds for which the vehicle is intended.

4. Two vehicles of identical dimensions but of different weights, running at the same speed on the same track will have identical riding qualities provided that the coefficients

A and $\frac{A^2 P}{aa' p}$ apply equally to both.

Consequently, it is only necessary to select the vehicle that rides the best, ascertain the value of the said coefficients, and apply them to all other vehicles of the same dimensions. It will be possible then to improve the riding of all the rolling stock to match that of the vehicle found to ride the best.

5. In order to give better riding it is important to aim at flexible springing, since this is accompanied by smaller amplitudes of oscillation, lower frequencies and lower accelerations. On the other hand, consideration of the critical and favourable speed ranges calls for a stiffer suspension as the normal running speeds are increased.

Our investigation makes it possible to estimate the importance of these conflicting requirements, and to arrive at the best choice of characteristics for the suspension.

6. In view of the current trend towards higher operating speeds, it would be more convenient to choose for future rolling stock a harder suspension, offset by an increase in the distance between axles in the bogies and an increase in the distance between the bogies themselves.

7. Damping of the springs reacts favourably upon the frequency, the acceleration and the amplitude of oscillation, and strongly opposes the influence of critical and favourable speeds, but, while it reduces oscillation as such, it does enhance the effect of sudden shocks. It follows therefore that damping must not be carried too far and that it must be combined with softening of the suspension.

* * *

The foregoing study being purely theoretical, we have carried out a variety of experiments to test the agreement between theory and practice.

The first series covered vehicles of differing characteristics such as restaurant cars 3681 and 4022, sleeping-car 3828 and Pullman car 4002. They confirmed the existence of a succession of critical and favourable speeds between 60 and 120 km/h, and these were found to coincide *exactly* with the calculated speeds. The trials confirmed the preponderating influence of the critical speeds, governed by the distance between rail joints as indicated by the theory.

For the second series of tests, we modified the suspension of a selected vehicle of a type known for its particularly hard springing. In one case (sleeping-car 3505), the total deflection A was increased from 17 to 20 cm; and in another (sleeping-car 3947), the coefficient A was taken from 12 to 19 cm. There was in each case a considerable improvement in the riding, which became comparable with that of coaches known to ride well, for which A lies between 18 and 20 cm. The experiments with these two vehicles confirmed the existence of critical and favourable speeds, which, as in the first test series, were found to coincide with the calculated values.

From this encouraging agreement between theory and practice, we have drawn two conclusions :

1° That we could design a two-stage suspension, *using helical coil springs* throughout, one stage of which (the softer) would be fitted with dampers. This new suspension will shortly go on trial.

2° That the publication of this theoretical study would be justified by the fact that experimental confirmation of the results had freed it from any suggestion of being purely mathematical speculation.

CORRIGENDUM

BULLETIN FOR MARCH 1954. — REPORT BY Prof. Dr. Ing. C. GUZZANTI

Question 3 (London Congress, 1954).

Page 338bis (table) : Appendix No. 2.

The following information relative to HOLLAND must be altered as hereafter :

	<i>There is :</i>	<i>It must be :</i>
A. 8. Passenger service		
(a) Gross ton-km per annum. .	1 752 448 567 .	8 224 888 851 (1952)
(b) Trailing ton-km per annum.	1 420 581 161	7 893 021 445 (1952)
A. 14. (a) Total consumption for traction, kWh/per annum.	450 000 000 (estimated for 1953)	392 000 000 (1952)

Pages 402/158 and 403/159 : Appendix No. 39.

Owing to the above mentioned alterations, the following figures must be altered as indicated hereunder :

(a) Annual consumption kW-h per gross ton km

Holland (1 500 V DC)

Instead of :

$$\frac{450\,000\,000}{1\,752\,448\,567 + 3\,906\,710\,378} = 0.079$$

It must be :

$$\frac{392\,000\,000}{8\,224\,888\,851 + 3\,906\,710\,378} = 0.032$$

(b) Annual consumption kW-h per nett ton km, freight and passenger

Holland (1 500 V DC)

Instead of :

$$\frac{450\,000\,000}{1\,420\,581\,161 + 3\,460\,692\,314} = 0.092$$

It must be :

$$\frac{392\,000\,000}{7\,893\,021\,445 + 3\,460\,692\,314} = 0.035$$

MONTHLY BIBLIOGRAPHY OF RAILWAYS⁽¹⁾

PUBLISHED UNDER THE SUPERVISION OF

P. GHILAIN,

General Secretary of the Permanent Commission of the International Railway Congress Association.

(JULY 1954)

[016. 385. (02)

I. — BOOKS.

In French.		
1953	691 & 721 .9	
GUERRIN (A.) & DANIEL (G.).		
Le calcul des tuyaux en béton armé et non armé.		
Paris, Editions Eyrolles. Un volume relié (16.5 × 25 cm)		
de 312 pages. (Prix : 3 300 fr. fr.)		
1953	621 .8	
EDELDT (P.M.).		
Convertisseurs de couple. Transmissions automatiques.		
Traduit et adapté par J. CASTELLAN.		
Paris, Dunod, éditeur. Un volume (16 × 25 cm) de		
40 pages, avec 300 figures. (Prix: relié, 3 280 fr. fr.)		
1953	621 .392 (06 (493)	
Journées de la Soudure organisées par la Section de		
Liège de l'A.I.Lg. à l'occasion de la Foire Internationale		
de Liège (30 avril-1 ^{er} et 2 mai 1953).		
Numéro de mai 1953 de la <i>Revue Universelle des Mines</i> ,		
2, quai Paul van Hoegaerden, Liège. Fascicule spécial		
(1 × 30 cm) de 176 pages, illustré, donnant le compte		
rendu de cette Session. (Prix: 125 fr. belges.)		
1953	744	
HENERT (G.) & PELLETIER (J.).		
Cours de dessin technique. (Travaux publics et Bâti-		
ment.)		
Paris, Eyrolles, éditeur. Un volume de 370 pages,		
36 figures, 21 tableaux et 23 planches. (Prix: 2 350 fr. fr.)		
1953	691	
UPFER (G.).		
Pratique du coffrage en bois et du ferrailage. Adapté		
présenté par L. BOURGINE.		
Paris, Eyrolles, éditeur. Un volume (19 × 27 cm) de		
20 pages, avec 129 figures. (Prix: 980 fr. fr.)		
1953	62 (01	
HERMITE (R.).		
Résistance des matériaux théorique et expérimentale.		
ome I: <i>Théorie de l'élasticité et des structures élastiques</i> .		
Paris, Dunod, éditeur. Un volume (16 × 25 cm) de		
76 pages, avec 384 figures. (Prix: relié, 8 400 fr. fr.)		
1953	62 (01	
ANUEL (G.).		
Résistance des matériaux.		
Paris, Dunod, éditeur. Un volume (16 × 25 cm) de		
54 pages, avec 190 figures. (Prix: 1 860 fr. fr.)		
1953	697	
MISSENARD (A.).		
Cours supérieur de chauffage, ventilation et condition-		
nement de l'air. Volume 4, 2 ^e édition.		
Paris, Editions Eyrolles. Un volume (17 × 25 cm)		
de 228 pages, avec 98 figures. (Prix: 1 300 fr. fr.)		
1953	721	
RAES (A.C.).		
Acoustique architecturale.		
Paris (V ^e), Editions Eyrolles, 61, boulevard Saint-		
Germain. Un volume (16.5 × 25 cm) de 194 pages, avec		
127 figures. (Prix: relié, 1 400 fr. fr.)		
In German.		
1954	69	
ECKART (H.P.).		
Handbuch des Bauwesens 1954. Der Deutsche Bauka-		
lender (76. Jahrgang) vereinigt mit Baustofflexikon.		
Stuttgart, Deutscher Fachzeitschriften- und Fachbuch-		
Verlag G.m.b.H. Ein abgeschlossener Band von über		
700 Seiten. (Format: 10.5 × 16.5) mit über 250 Abbil-		
dungen, Zeichnungen, Details und zahlreichen Tabellen.		
(Preis: 14.40 DM.)		
1954	625 .2 & 691	
Kautschuk im Eisenbahnbau.		
Sonderausgabe von ETR. <i>Eisenbahntechnische Rund-</i>		
<i>schau</i> . März 1954. Referate der Tagung des Internationa-		
len Kautschukbüros anlässlich der DVA 1953 in München.		
Darmstadt, Carl Röhrig-Verlag oHG, 8, Stephan-		
strasse. Ein Heft (21 × 30 cm) mit etwa 80 Seiten und		
Abbildungen. (Preis: DM 8.— einschliesslich Versand-		
kosten; Vorzugspreis für ETR-Bezieher: DM 6.—.)		
1954	621 .335	
Dr. techn. Karl SACHS.		
Elektrische Triebfahrzeuge.		
Frauenfeld (Schweiz), Schweizerischer Elektrotechni-		
scher Verein, Kommissionsverlag Huber & Co., A.G.		
Ein Handbuch für die Praxis sowie für Studierende in		
2 Bänden: 1. Band, 700 Seiten mit 847 Textabbildungen;		
2. Band, 696 Seiten mit 850 Textabbildungen und		
16 Tafeln. (Preis: beide Bände in Leinen gebunden		
und in Futteral, 65 Schw. Fr.)		

(1) The numbers placed over the title of each book are those of the decimal classification proposed by the Railway Congress. jointly with the Office Bibliographique International, of Brussels. (See « Bibliographical Decimal Classification as applied to Railway. ence », by L. WEISSENBRUCH, in the number for November 1897, of the *Bulletin of the International Railway Congress*, p. 1509.)

1953 69 (02)
Dr.-Ing. E.h. Bernhard WEDLER.
Berechnungsgrundlagen für Bauten. 22. Ausgabe.
Berlin-Wilmersdorf, Wilhelm Ernst & Sohn, Hohen-
zollerndam 169. Ein Band (15 × 21 cm), VIII + 463
Seiten mit 277 Abbildungen. (Preis: gebunden, 7.50 DM).

In English.

1953 621 .132.1 (42)
AHRONS (E.L.).
Locomotive and train working in the latter part of the
nineteenth century. (Volume 5.)
Edited by L.L. ASHER. Publishers: W. Haeffer & Sons
Ltd., Cambridge. Price: 15 sh. net.

1953 385 (061.4)
AMERICAN RAILWAY ENGINEERING ASSOCIA-
TION BULLETIN, No. 509, vol. 55, June-July.
1) Stress measurements and service tests of manganese
steel castings in the crossings at Mc. Cook, Illinois;
2) Investigation of dead-load and live-load stresses in a
350 ft. truss span on the AT and SF system;
3) Tie renewals and costs per mile of maintained track.
Publishers: The American Railway Engineering Asso-
ciation, 59, East Van Buren Street, Chicago 5, Illinois.
Subscription: \$ 10 per annum.

1953 31 & 656
ANNUAL BULLETIN OF TRANSPORT STATISTICS.
1952.
Published by the Economic Commission for Europe,
Transport Division, United Nations, Genève. United
Nations Publications. Sales Number: 1954. II. E. 1,
Price: 9 s.

1953 385 (061.4 (73) & 656 .25 (73)
ASSOCIATION OF AMERICAN RAILROADS. Signal
Section.
Report to be presented at the Fifty-Fifth Annual Meeting
St. Louis, Mo.-September 28, 29 and 30, 1953. (Vol. I,
No. 1).
Chicago 5, Ill. Published by the Signal Section A.A.R.,
59, East Van Buren Street. (Subscription: \$ 3 and \$ 6
per annum.)

016. 385. (05]

II. — PERIODICALS.

In French.

Annales des ponts et chaussées. (Paris.)
1953 624 .2
Annales des ponts et chaussées, mai-juin, p. 245.
GRIVEAUD (J.). — Complément à l'étude des
poutres échelles. (8 000 mots, tableaux & fig.)
1953 62 (01
Annales des ponts et chaussées, novembre-décembre,
p. 623.
DAVIN. — Stabilité, courbe intrinsèque et courbes de
traction et compression d'un matériau répondant à
certaines conditions de structure. (10 000 mots, tableaux
& fig.)

1953 385 (09 (42)
KIDNER (R.W.).
The South Eastern Railway.
Publishers: The Oakwood Press, Tanglewood, South
Godstone, Surrey. Price: 10 s. 6 d.

1953 385 (09 (42)
ROBBINS (M.).
The Isle of Wight Railways.
Publishers: The Oakwood Press, Tanglewood, South
Godstone, Surrey. Price: 7 s. 6d.

1953 621 .132.1 (931)
NEW ZEALAND RAILWAY ENGINES.
One volume (6 × 8 3/4 in.) of 32 pages, illustrated
Paper covers.
Publishers: New Zealand Railway & Locomotive
Society, 30, Plunket Avenue. Petone - New Zealand.
Price: 5 s.

1953 3
STATISTICAL YEARBOOK (Annuaire Statistique) 1953
Fifth Issue (*Cinquième année.*)
Prepared by the Statistical Office of the United Nations
Department of Economic Affairs. New-York.
United Nations Publications. Sales No. 1953-XVII-9
Clothbound: \$ 7.50. Paper bound: \$ 6.00.

1953 385 (0
THE DIRECTORY OF RAILWAY OFFICIALS &
YEAR BOOK 1953-1954.
One volume (8 1/2 × 5 1/2 in.) of 530 pages.
Publishers: Tothill Press Limited, 33, Tothill Street
Westminster, London S.W.1. Price: 40 s.

1953 621 .333 (73)
UNIVERSITY OF ILLINOIS BULLETIN, serie
No. 418.
FAUCET (M.A.), FISCHER (M.) Jr. and HELM (M.S.).
Effect of polyphase motors on the voltage regulation
of circuits supplying three-phase welder loads.
A publication of 42 pages obtainable from the Office
of Publication, 358, Administration Building, Urbana,
Illinois, U.S.A. Price: 40 cents.

Bulletin des C.F.F. (Berne.)

1953 621 .335 (494)
Bulletin des C.F.F., septembre, p. 132.
Nouvelles automotrices doubles d'excursion. (1 100 mots
& fig.)

1953 656 .212.
Bulletin des C.F.F., octobre, p. 150.
WILDHABER (P.). — Les palettes de particulier
dans le service des marchandises. (2 700 mots & fig.)

1953 625 .26 (494)
Bulletin des C.F.F., octobre, p. 153.
WEBER (M.). — A propos des frais de revision de
voitures. (800 mots.)

Bulletin de la Société des Ingénieurs civils de France. (Paris.)

1953 621 .33
Bull. de la Soc. des Ing. civils de France (mémoires),
mai-juin, p. 186.
ARMAND (L.). — Autour des nouvelles techniques
de l'électrification des chemins de fer. (6 000 mots & fig.)

Bulletin des transports internationaux par chemins de fer. (Berne.)

1953 385 .62
Bulletin des transports internationaux par chemins de
fer, juin (*Annexe*), pp. 105 à 136.
Convention internationale concernant le transport des
voyageurs et des bagages par chemin de fer (CIV) du
25 octobre 1952.

1953 385 .113 (494)
Bulletin des transports internationaux par chemins de
fer, août, p. 248.
Rapport des Chemins de fer Fédéraux sur la gestion
et les comptes de l'année 1952. (1 500 mots).

Bulletin de l'Union internationale des Chemins de fer. (Paris.)

1953 0
Bulletin de l'Union intern. des Ch. de fer, juillet-août,
p. 191.
TOUGNE (J.). — La classification décimale univer-
selle. (1 500 mots.)
1953 385 .62 & 385 .63
Bulletin de l'Union intern. des Ch. de fer, septembre-
octobre, p. 223.
MERMET (E.). — La révision des Conventions de
Berne. (5 000 mots.)

Economie et Technique des Transports. (Zurich.)

1953 621 .335 (494)
Economie et Technique des Transports, n° 1-3, p. 5;
n° 4-6, p. 45.
WATTENHOFER (A.). — Nouveau matériel roulant
du Chemin de fer Bex-Villars-Bretaye. (2 100 mots & fig.)
1953 621 .335 (45)
Economie et Technique des Transports, n° 7-9, p. 84.
HUG (Ad.-M.). — Die elektrischen Gelenkschnelltrieb-
züge, Reihe ETR300, der Italienischen Staatsbahnen.
1 000 mots & fig.)

Génie Civil. (Paris.)

1953 624 .2 & 691
Génie Civil, n° 3360, 1^{er} novembre, p. 411.
COÛARD (A.). — La fissuration des poutres en béton
armé. (1 500 mots.)
1953 691
Génie Civil, n° 3361, 15 novembre, p. 421.
LOSSIER (H.). — Du béton armé au béton précon-
crêt. (2 500 mots & fig.)

1953 621 .332
Génie Civil, n° 3361, 15 novembre, p. 424.
L'utilisation de rails conducteurs soudés de grande
longueur sur les Chemins de fer Britanniques. (500 mots.)

1953 .62 (01)
Génie Civil, n° 3362, 1^{er} décembre, p. 453.
COÛARD (A.). — Cisaillement sous traction ou sous
compression. (1 000 mots.)

L'Ossature métallique. (Bruxelles.)

1953 624 .51 (73)
L'Ossature métallique, juin, p. 328.
Le pont de la baie de Chesapeake (U.S.A.). (2 000 mots
& fig.)

1953 691
L'Ossature métallique, juin, p. 333.
BERMANNE (D.). — Protection des constructions
métalliques contre la corrosion atmosphérique. (4 000 mots
& fig.)

1953 624 .32 (44)
L'Ossature métallique, juillet-août, p. 393.
DELCAMP (A.). — Reconstruction du pont de la
Bleuze-Borne sur l'Escaut à Valenciennes. (2 000 mots
& fig.)

1953 624 (0
L'Ossature métallique, septembre, p. 455.
MASSONET (Ch.). — Détermination expérimentale
des lignes d'influence des constructions hyperstatiques
sans emploi de microscopes. L'influentiomètre du pro-
fesseur Eney. (4 500 mots & fig.)

1953 624 .32 (494)
L'Ossature métallique, octobre, p. 497.
FREI (M.). — Le pont-route sur l'Aar près de Schinz-
nach-Bad. (1 500 mots & fig.)

Rail et Traction. (Bruxelles.)

1953 621 .431.72
Rail & Traction, n° 24, avril-mai, p. 3 ; juin-juillet, p. 3 ;
août-septembre, p. 15 ; octobre-décembre, p. 41.
VAN GEEL (P.). — La traction diesel, son passé et
son avenir. (10 500 mots & fig.)

Revue de l'Aluminium. (Paris.)

1953 625 .3 (43)
Revue de l'Aluminium, mai, p. 210.
Le train monorail ALWEG. (1 000 mots & fig.)

Revue Générale des Chemins de fer. (Paris.)

1953 621 .335 (44)
Revue Générale des Chemins de fer, novembre, p. 589.
DUFÊTRE, COUREAU, HEIDMANN, BODMER
& ROSSIGNOL. — Les locomotives électriques à
grande vitesse BB 9003/9004. (9 000 mots & fig.)

1953 656 .212.7 (44)
Revue Générale des Chemins de fer, novembre, p. 613.
DELACARTE & PATIN. — **Transport des automobiles par le Tunnel du Fréjus.** (1 500 mots & fig.)

1953 625 .171
Revue Générale des Chemins de fer, novembre, p. 618.
ROSEAU. — **L'interprétation des enregistrements Mauzin.** (4 000 mots & fig.)

1953 625 .173 (44)
Revue Générale des Chemins de fer, novembre, p. 631.
RENOT. — Une « **substitution** » de **voies principales lourdes** par de nouveaux moyens mécaniques. (2 000 mots & fig.)

1953 621 .332 (44)
Revue Générale des Chemins de fer, novembre, p. 639.
Transformation à 25 000 V de la ligne d'essais à 20 000 V de traction électrique monophasée à 50 périodes d'Aix-les-Bains à La Roche-sur-Foron. (1 000 mots.)

1953 621 .335 (44)
Revue Générale des Chemins de fer, décembre, p. 649.
HEFTI (W.) & FEDDERSEN (A.). — **Les locomotives électriques BB 9001/9002** de la S.N.C.F. (6 000 mots & fig.)

1953 656 .213 (44)
Revue Générale des Chemins de fer, décembre, p. 665.
LEGRAND. — **La nouvelle gare de voyageurs** de Dieppe-Maritime. (2 000 mots & fig.)

1953 621 .431.72 (44)
Revue Générale des Chemins de fer, décembre, p. 673.
OLIVE. — **Les locotracteurs Diesel-hydrauliques** de 400 ch séries Y9100 et Y9200 de la S.N.C.F. (3 000 mots & fig.)

1953 385 (06 4)
Revue Générale des Chemins de fer, décembre, p. 687.
Création d'une Conférence Européenne des Ministres des Transports (Session de Bruxelles, octobre 1953.) (1 000 mots.)

1953 625 .285 (45)
Revue Générale des Chemins de fer, décembre, p. 694.
Les nouveaux autorails des Chemins de fer Italiens à moteur horizontal de 460/480 ch disposé sous la caisse. (1 300 mots, tableaux & fig.)

1954 656 (44)
Revue Générale des Chemins de fer, janvier, p. 1.
LEFORT. — **Gares routières et liaison fer-route** sur la Région de l'Est de la S.N.C.F. (3 000 mots & fig.)

1954 625 .233 (44)
Revue Générale des Chemins de fer, janvier, p. 9.
RIMBAUD (L.) & DIDIER (R.). — **L'éclairage par lampes fluorescentes** des voitures de la S.N.C.F. (5 000 mots & fig.)

1954 385 .113 (44)
Revue Générale des Chemins de fer, janvier, p. 20.
La gestion de la S.N.C.F. en 1952. (3 500 mots & tableaux.)

1954 625 .26 (44)
Revue Générale des Chemins de fer, janvier, p. 27.
FOISSAC-GEGOUX & CUVELIER. — **L'organisation des chantiers** par la méthode des temps élémentaires. **La réparation des roues** aux ateliers d'Hellemmes. (3 000 mots & fig.)

1954 656 .254 (44)
Revue Générale des Chemins de fer, janvier, p. 38.
La sécurité aux passages à niveau. (800 mots & fig.)

1954 621 .338 (45)
Revue Générale des Chemins de fer, janvier, p. 40.
HUG (Ad.-M.). — **Les rames motrices électriques de luxe à grande vitesse** des Chemins de fer Italiens de l'Etat. (1 000 mots & fig.)

Revue de l'Union internationale des Transports Publics. (Bruxelles.)

1953 625 .42 (460)
Revue de l'Union Intern. des Transports publics, n° 1, II, p. 57.
OTAMENDI (M.). — **Le Chemin de fer Métropolitain de Madrid.** (1 500 mots & fig.)

1953 625 .6
Revue de l'Union Intern. des Transports publics, n° 2, II, p. 117.
PATRASSI (A.). — **Analyse du coût d'exploitation des Transports publics.** (6 500 mots & tabl.)

1953 621 .431.72
Revue de l'Union Intern. des Transports publics, n° 3, II, p. 191.
TOURNEUR. — **Les transmissions hydromécaniques pour la traction ferroviaire.** (2 000 mots & fig.)

1953 656
Revue de l'Union Intern. des Transports publics, n° 3, II, p. 217.
PERIDIER (J.). — **Considérations sur l'évolution des transports publics de voyageurs.** (5 000 mots.)

Trains. (Bruxelles.)

1953 621 .335 (493)
Trains, n° 13, pp. 5 et 13.
BAEYENS (F.). — **Nouvelles automotrices électriques** de la S.N.C.B. (1 500 mots & fig.)
Les futures locomotives électriques de la S.N.C.B. (1 500 mots & fig.)

1953 621 .33 (493)
Trains, n° 15, p. 1.
BAEYENS (F.). — **20 ans de traction électrique** à la S.N.C.B. (2 000 mots & fig.)

1953 621 .431.72 (493)
Trains, n° 15, p. 9.
BOULANGER (S.). — **Le développement de la traction Diesel** à la S.N.C.B. (4 000 mots & fig.)

1953 656 .211.
Trains, n° 16, p. 1.
LENFANT (H.). — **La protection des voyageurs contre les intempéries** pendant leur séjour ou leur passage sur les quais des gares. (5 000 mots & fig.)

Travaux. (Paris.)

- 1953 624 .32 (44)
Travaux, juin, p. 305.
COURBON (J.). — Le projet de reconstruction du pont de Saint-Mathurin, sur la Loire. (3 000 mots & fig.)
- 1953 656. 213 (65)
Travaux, juin, p. 311.
GABRIEL (J.). — La nouvelle gare maritime du port d'Alger. Les travaux de première étape. (3 500 mots & fig.)
- 1953 62 (01 & 691)
Travaux, juin, p. 319; juillet, p. 349.
DURIEZ (M.). — Action de l'eau de mer et des eaux agressives sur les chaux et ciments. Comportement des mortiers et bétons hydrauliques. — Cas particulier du béton armé. Causes et effets. — Prévention et remèdes. (Suite.) (9 000 mots & fig.)
- 1953 624 .2
Travaux, juillet, p. 339.
MOUGENOT (E.). — La poutre la plus économique. (3 000 mots & fig.)

La Vie du Rail. (Paris.)

- 1953 621 .431.72 (44)
La Vie du Rail, 20 juillet, p. 4.
Locomotives Diesel-électriques de 2 000 ch pour trains de marchandises. (500 mots & fig.)
- 1953 621 .431 .72 (44)
La Vie du Rail, 6 septembre, p. 6.
Locotracteurs Diesel hydrauliques de 400 ch série Y9100 (600 mots & fig.)
- 1953 656 .212 (44)
La Vie du Rail, 13 septembre, p. 9; 11 octobre, p. 8.
TEXTE. — Les « marchés-gares ». La gare-marché de Lyon. (4 500 mots & fig.)
- 1953 621 .335 (44)
La Vie du Rail, 20 septembre, p. 3.
Lés BB prototypes 9001-9002. (1 500 mots & fig.)

In German.

- Der Eisenbahningenieur. (Frankfurt a. Main.)
- 1953 621 .33
Der Eisenbahningenieur, Juli, S. 154.
DUVENBECK (B.). — Die elektrische Zugförderung. Wirtschaftlichkeit und Umstellungsplanungen. (3 000 Wörter & Abb.)
- 1953 625 .13
Der Eisenbahningenieur, Juli, S. 170.
LIEBE (R.). — Das Tunnelgerät « Trier ». (1 700 Wörter & Abb.)

- 1953 625 .144.4
Der Eisenbahningenieur, August, S. 196.
SCHMELZER. — Verbindung von Gleichhebewinden und Gleisstopfmaschinen. (600 Wörter & Abb.)

- 1953 625 .212
Der Eisenbahningenieur, August, S. 198.
HINTERWÄLDER (K.). — Beitrag zum Vermessen von Radsätzen von Lokomotiven und Wagen. (1 100 Wörter & Abb.)

- 1953 624 (43) & 691 (43)
Der Eisenbahningenieur, September, S. 206.
KONRATH (H.). — Herstellen einer Spannbeton-Eisenbahnbrücke und Einschieben in einer Betriebspause. Umbau der Unterführung Schwanheimer Strasse in Frankfurt am Main-Niederrad. (1 500 Wörter & Abb.)

- 1953 625 .143 .4
Der Eisenbahningenieur, September, S. 214.
ARNOLD (J.). — Beseitigung von Mängeln an isolierten Schienenstößen. (2 000 Wörter & Abb.)

- 1953 625 .28 (43)
Der Eisenbahningenieur, September, S. 219.
HARRES (H.). — Rationalisierungsmassnahmen des Betriebsmaschinenendienstes. (2 500 Wörter.)

- 1953 625 .144 .2
Der Eisenbahningenieur, September, S. 222.
HELL (H.). — Das Einkämmen von Brückenschwellen in Stahlträger bei überhöhten Gleisen. (4 500 Wörter & Abb.)

Eisenbahntechnik. (Berlin.)

- 1953 621 .33
Eisenbahntechnik, Heft 4, August, S. 145.
REINGRUBER (H.). — Zur Frage der Elektrifizierung von Fernbahnen. (5 500 Wörter & Abb.)

- 1953 621 .13 (438)
Eisenbahntechnik, Heft 4, August, S. 160.
Einige Typen Polnischer Lokomotiven. (1 600 Wörter & Abb.)

- 1953 625 .258
Eisenbahntechnik, Heft 4, August S. 164.
POTTHOFF (G.). — Die Bremswirkung von Balken-gleisbremsen. (4 000 Wörter & Abb.)

- 1953 625 .23
Eisenbahntechnik, Heft 5, September, S. 195.
MÜSSIG (W.). — Der Eisenbahnwagenbau. (4 000 Wörter & Abb.)

- 1953 656 .21
Eisenbahntechnik, Heft 5, September, S. 205.
GERHART & POTTHOFF. — Ueberholungsgleise. (4 000 Wörter, Tafeln & Abb.)

- 1953 621 .133.1
Eisenbahntechnik, Heft 5, September, S. 213.
ERLER (H.-J.). — Braunkohlenbrikettfeuerung im Lokomotivbetrieb. (3 000 Wörter & Abb.)

E.T.R. Eisenbahntechnische Rundschau. (Köln-Darmstadt.)

1953 625 .24 (4)
Eisenbahntechnische Rundschau, Juni-Juli, S. 326;
August-September, S. 461.
RAAB (K.). — Der Weg zum europäischen Güter-
wagen. (11 000 Wörter & Abb.)

1953 625 .143 (43)
Eisenbahntechnische Rundschau, Juni-Juli, S. 374;
August-September, S. 453.
MEIER (H.). — Die Verbesserung der Eisenbahn-
schiene. Ein Ueberblick über die gegenwärtigen Bemü-
hungen der Deutschen Bundesbahn. (13 000 Wörter &
Abb.)

1953 621 .431 .72: 656 .27
Eisenbahntechnische Rundschau, Juni-Juli, S. 365.
FRIEDRICH (K.). — Fortschrittlicher Dieselleicht-
verkehr mit Schienenomnibussen. (5 000 Wörter & Abb.)

1953 621 .13 (43)
Eisenbahntechnische Rundschau, August-September,
S. 389.

WITTE (F.). — Die neuen Baugrundsätze bei Entwick-
lung der seit 1945 gebauten Dampflokomotiven der
Bundesbahn und ihre Anwendung auf die 1'CI'-h²
Personenzuglokomotive Reihe 23. (13 000 Wörter & Abb.)

1953 625 .13
Eisenbahntechnische Rundschau, August-September,
S. 424.

BARTH, KLEIN & RAAB. — Entlüftung von Tunneln
und Stollen durch Schacht- und Längsgebläse. (8 500
Wörter & Abb.)

1953 625 .21
Eisenbahntechnische Rundschau, August-September,
S. 444.

FAHLBUSCH (H.). — Ein Beitrag zur Berechnung
selbsttragender Eisenbahnwagenkästen. (4 500 Wörter
& Abb.)

1953 625 .26
Eisenbahntechnische Rundschau, Oktober, S. 513.

MARTIN (E.). — Das Materialprüfwesen im Dienste
der Fahrzeugerhaltung. (4 000 Wörter & Abb.)

Elektrische Bahnen. (München.)

1953 621 .335 (494)
Elektrische Bahnen, Juli, S. 162.

MÜLLER (A.E.) und BORGEAUD (G.). — Neu-
zeitliche Schweizerische Einphasen-Wechselstrom-Loko-
motiven. (6 000 Wörter & Abb.)

1953 621 .333
Elektrische Bahnen, Juli, S. 175.

MICHEL (O.). — Die Wicklungserwärmung beim
Bahnmotor und ihre Messung im Prüffeld. (3 000 Wörter
& Abb.)

1953 625 .2
Elektrische Bahnen, Juli, S. 179.

SCHIPPER (P.) & JAXTHEIMER (W.). — Die
Schleuderschutzeinrichtung (Bauart BZA Mü). (600 Wör-
ter & Abb.)

1953 621 .331 (43)
Elektrische Bahnen, August, S. 185.
ALZMANN (M.). — Das Dampfkraftwerk Penzberg
der Deutschen Bundesbahn. (13 000 Wörter & Abb.)

1953 621 .33
Elektrische Bahnen, August, S. 199.
AKERMAN (O.). — Die Entwicklungsmöglichkeiten
für den elektrischen Einphasenbetrieb durch sogenannte
Multiplexzüge. (1 700 Wörter & Abb.)

1953 621 .335 (494)
Elektrische Bahnen, September, S. 209.
MEYER (E.). — Die elektrische Schnellzuglokomotive
Ae 6/6 für die Gotthardstrecke der Schweizerischen
Bundesbahnen. (5 000 Wörter & Abb.)

1953 621 .333
Elektrische Bahnen, September, S. 224.
DIETRICH (J.). — Schreibende Taschen-Messgeräte
zum Prüfen von Kommutator- und Bürstenhaltern in
Bahnmotoren. (5 500 Wörter & Abb.)

Glaser's Annalen. (Berlin.)

1953 625 .214
Glaser's Annalen, August, S. 219.
MUNDT (R.). — Berechnung und Konstruktion von
Rollenschlagern. (5 500 Wörter & Abb.)

1953 656 .22 (43)
Glaser's Annalen, August, S. 227.
HARRES (H.). — Strukturwandlung im Zugförder-
dienst der Deutschen Bundesbahn. (9 000 Wörter
& Abb.)

1953 625 .3 (43)
Glaser's Annalen, August, S. 239.
HINSKEN (J.). — Probleme der Alweg-Bahn. (3 000
Wörter & Abb.)

1953 625 .212
Glaser's Annalen, September, S. 264.
MÜLLER (C. Th.). — Der Eisenbahnradatz.
Kinematik, Spurführungsgeometrie und Führungsver-
mögen. (11 000 Wörter & Abb.)

1953 621 .431 .72
Glaser's Annalen, Oktober, S. 285.

GAEBLER (G.A.). — Verwendbarkeit und Wirtschaft-
lichkeit von Brennkraftantrieben für Eisenbahnfahrzeuge
unter besonderer Berücksichtigung der Einflüsse des
Fahrzeuggestaltbaues. (5 000 Wörter, Tafeln & Abb.)

Internationales Archiv für Verkehrswesen. (Mainz.)

1953 625 .2 & 625 .28
Int. Archiv. für Verkehrswesen, Nr. 9, 1. Maiheft, S. 189.
HERRMANN (M.). — Technische Entwicklungsten-
denzen im Eisenbahnwesen. (8 000 Wörter)

1953 **621** .332 (43)
Int. Archiv. für Verkehrswesen, Nr. 9, 1. Maiheft, S. 203.
Auswirkungen einer etwaigen Änderung des deutschen Bahnstromsystems. Stellungnahme zu der Abhandlung unter dieser Überschrift, von R. FRITSCHKE, Heft 20, Seite 473-478. (3 000 Wörter.)

1953 **656** .224 (43)
Int. Archiv. für Verkehrswesen, Nr. 9, 1. Maiheft, S. 207.
Rationalisierung des Personenverkehrs. (1 000 Wörter.)

1953 **656** (494)
Int. Archiv. für Verkehrswesen, Nr. 10, 2. Maiheft, S. 213.
LEIBBRAND (K.). — Schweizerische Verkehrsfragen. (5 000 Wörter.)

In English.

Electrical Engineering. (New York.)

1953 **621** .431 .72
Electrical Engineering, October, p. 877.
Mc. DONALD (G.R.). — Diesel-electric locomotive ground relays. (650 words and figs.)

1953 **625** .17 (73)
Electrical Engineering, October, p. 898.
BRAUNS (J.-W.). — A track-laying shuttle car. (700 words and figs.)

1953 **621** .431.72 (71)
Electrical Engineering, October, p. 926.
SYLVESTER (J.-D.) and HANEY (D.-F.). — Diesel electric locomotives in Canada. (700 words and figs.)

The Engineer. (London.)

1953 **621** .131.3 (42)
The Engineer, July, 24, p. 103; July 31, p. 136; October 2, p. 424; October 9, p. 451.

NOCK (O.S.). — Performance and efficiency tests of the « Britannia » locomotives. (9 000 words & figs.)

1953 **621** .431.72 (94)
The Engineer, July 24, p. 108.
Diesel-electric locomotives for Australia. (2 500 words & figs.)

1953 **656** .212.8 (42)
The Engineer, July 24, p. 118.
Railway vehicle re-railing equipment. (1 200 words & figs.)

1953 **621** .132.1 (42)
The Engineer, August 21, p. 231.
POULTNEY (E.C.). — Some locomotives of 1903. (3 500 words and figs.)

1953 **625** .144.4 (42)
The Engineer, August 28, p. 280.
Ballast cleaning on British Railways. (360 words and figs.)

Engineering. (London.)

1953 **621** .431.72 (943)
Engineering, August, p. 172.
1 500 HP Diesel-electric locomotive for Queensland Railways. (1 200 words & figs.)

1953 **621** .431.72 (73)
Engineering, August 21, p. 233.
Variable gauge Diesel-electric locomotives. (400 words.)

1953 **625** .143 (42)
Engineering, September 4, p. 299.
GOODEVE (Charles-F.). — The milling of rail ends and its effect on productivity. (550 words.)

1953 **656** .2 (42)
Engineering, September 4, p. 305.
Steam and Diesel on trial. (1 650 words.)

1953 **621** .132.1 (42)
Engineering, September 11, p. 348.
Standard 2-6-2 tank locomotives, British Railways. (1 000 words and figs.)

1953 **656** .212.6 (42)
Engineering, September 25, p. 395.
Diesel electric mobile crane. (1 500 words & fig.)

1953 **621** .33 (42)
The Engineering, October 9, p. 459.
50-cycle single-phase electrification on British Railways. (1 200 words & figs.)

The Journal of the Institute of Transport. (London.)

1953 **656** .23 (42)
The Journal of the Institute of Transport, September, p. 216.
PIKE (J.-R.). — Trends and influences in transport charges. (7 000 words.)

Proceedings of the Institution of Civil Engineers. (London.)

1953 **625** 4. (42)
Proceedings of The Institution of Civil Engineers, October, p. 605.
COOMBS (D.-H.) and WILLSON (G.-J.). — The trend of development in the design and equipment of underground railways. (14 000 words, figs & tables.)

The Proceedings of the Institution of Electrical Engineers. (London.)

1953 **656** .25
The Proceedings of the Institution of Electrical Engineers, August, p. 362.
FROST-SMITH (E.H.). — The study of a magnetic inverter for amplification of low- input-power D.C. signals. (5 100 words & figs.)

Journal of the Institution of Locomotive Engineers. (London.)

1953 625 .28
Journal of the Institution of Locomotive Engineers,
Vol. 43, p. 12.

DEN HOLLANDER (Ir.F.Q.). — **Efficiency in the
choice and application of locomotives.** (4 100 words and
figs.)

1953 625 .251; 621 .33
Journal of the Institution of Locomotive Engineers,
Vol. 43, p. 85.

ROBERTSON (A.S.). — **Limitations of acceleration
and braking with electric traction.** (66 pages illustrated.)

1953 621 .138.5 (42)
Journal of the Institution of Locomotive Engineers,
Vol. 43 (part. n° 2), p. 175.

BOND (R.C.). — **Organisation and control of loco-
motive repairs on British Railways.** (29 000 words and
figs.)

1953 621 .438 (42)
Journal of the Institution of Locomotive Engineers,
Vol. 43, p. 268.

DYMOND (A.W.J.). — **Operating experiences with
two gas turbine locomotives.** (24 000 words & figs.)

1953 621 .431.72 (42)
Journal of the Institution of Locomotive Engineers,
Vol. 43, p. 366.

REED (B.). — **Running tests of a 500 HP Diesel
mechanical locomotive.** (15 000 words & figs.)

1953 621 .133 & 669
Journal of the Institution of Locomotive Engineers,
Vol. 43, part. No. 4, p. 475.

COMPTON (J.N.). — **The design and construction
of steel fireboxes.** (7 000 words & figs.)

Journal,

The Permanent Way Institution. (London.)

1953 656 .28
Journal, The Permanent Way Institution, August, p. 112.
CLARKE (H.W.). — **Accidents and derailments.**
(2 600 words.)

1953 625 .143
Journal, The Permanent Way Institution, August, p. 126.
SONNEVILLE (R.). — **The use of rubber rail pads
on the permanent way.** (1 650 words & figs.)

Journal and Proceedings, The Institution of Mechanical Engineers. (London.)

1953 62 & 656 .2
The Institution of Mechanical Engineers, Proceedings
Vol. 167, n° 2, p. 141.

RIDDLES (R.A.). — **Development of the engineer
in railway practice.** (4 600 words & figs.)

The Locomotive. (London.)

1953 621 .431.72 (944)
The Locomotive, August, p. 116.
Bo-Bo D-E locomotives for New South Wales. (1 300
words & figs.)

1953 621 .13
The Locomotive, August, p. 119.
SELLS.— **The Gold Coast Government Rly. and its
locomotives.** (2 700 words & figs.)

1953 621 .13 (73)
The Locomotive, August, p. 124.
G.N.R. (U.S.A.) 2-8-0-0-8-0 locos. (300 words & figs.)

1953 621 .335 (494)
The Locomotive, September, p. 135.
The new Co-Co Gotthard locos. (1 100 words & figs.)

1953 621 .431.72 (43)
The Locomotive, September, p. 136.
Diesel-hydraulic locomotives, German Railways.
(475 words & fig.)

Modern Transport. (London.)

1953 621 .431.72 (42)
Modern Transport, June 13, p. 3.
Standard Diesel-electric shunting locomotives. (1 500
words & figs.)

1953 621 .132.1 (73)
Modern Transport, June 20, p. 6.
POULTNEY (E.C.). — **Steam power on the Norfolk
and Western.** (900 words & figs.)

1953 385 .4 (42)
Modern Transport, June 27, p. 14.
British Transport Commission's record for 1952.
(2 800 words.)

1953 656 .211.7 (42 & 493)
Modern Transport, July 4, p. 3.
New train ferry terminal at Zeebrugge. (1 200 words
& figs.)

1953 385 (94)
Modern Transport, July 18, p. 7.
Australian Railways. — **Results of four systems in
1951-1952.** (1 600 words.)

1953 621 .431.72 (94)
Modern Transport, July 25, p. 3.
Diesel-electrics for Australia. (1 900 words and figs.)

1953 621 .131.3 (42)
Modern Transport, August 1, p. 3.
Testing B.R. locomotives. (1 100 words & figs.)

1953 621 .338 (43)
Modern Transport, August 8, p. 5.
German battery railcars. (500 words & figs.)

1953 621 .431.72 (44)
Modern Transport, August 8, p. 5.
French Diesel locomotives. (600 words & figs.)

- 1953** 625 .28 (42)
Modern Transport, August 8, p. 13.
New rail-less shunter. (500 words & figs.)
- 1953** 656 .212.6 (42)
Modern Transport, August 29, p. 3.
A new mobile crane. Walker Diesel electric for 6- to 8-ton lifts. (1 600 words & figs.)
- 1953** 625 .144.4 (42)
Modern Transport, August 29, p. 5.
Cleaning railway ballast. (350 words & figs.)
- 1953** 621 .132.1 (42)
Modern Transport, September 12, p. 9.
New standard tank engine. (1 100 words & figs.)
- 1953** 621 .431.72 (42)
Modern Transport, September 19, p. 7.
Testing B.R. Locomotives, Southern Region 1 750 HP Diesel Electric. (2 300 words & figs.)
- 1953** 625 .232
Modern Transport, September 19, p. 12.
BEHREND (G.). — Wagon-Lits progress (to be continued). (1 000 words & fig.)
- 1953** 625 .28 (42)
Modern Transport, September 26, p. 5.
BOND (R.C.). — Railway traction. Justification for British Motive Power Methods. (2 000 words.)
- 1953** 621 .33 (42)
Modern Transport, October 10, p. 11; October 17, p. 12.
Commercial frequency electric traction. (1 500 words & figs.)
- 1953** 621 .338 (494)
Modern Transport, November 14, p. 29.
New railway coaches in Switzerland. (500 words, figs & table.)
- 1953** 621 .431.72 (6)
Modern Transport, November 28, p. 3.
Two Diesel-hydraulic locomotives. (1 500 words & figs.)
- 1953** 656 .25
Modern Transport, December 19, p. 5.
HATLEY (L.W.). — Automatic train control. Railway safety measures. (1 800 words & figs.)

The Oil Engine and Gas Turbine. (London.)

- 1953** 621 .431 .72 (42)
The Oil Engine and Gas Turbine, Mid August, p. 128.
New double- engined 1 000 B.H.P. locomotives. (2 000 words & figs.)
- 1953** 621 .431.72 (43)
The Oil Engine and Gas Turbine, Mid August, p. 131.
Diesel-hydraulic trains in Germany. (1 350 words & figs.)
- 1953** 621 .431 .72 (73)
The Oil Engine and Gas Turbine, Mid September, p. 178.
Two new « flow production » locomotives. (1 500 words & figs.)

Occupational Safety and Health (Geneva.)

- 1953** 658 .28
Occupational Safety and Health, October-December, p. 163.
Causes of accidents in the coupling of railway vehicles and related operations and measures for their prevention. (10 500 words & figs.)

Railway Age. (New York.)

- 1953** 656 .23 (73)
Railway Age, October 5, p. 69.
Santa Fe car accounting... for speed and service, it's tops. (900 words & figs.)
- 1953** 625 .232 (460)
Railway Age, October 5, p. 77.
Demonstration and growth... three years of Talgo in Spain. (1 200 words & fig.)
- 1953** 625 .245 (73)
Railway Age, October 5, p. 80.
GM unveils trailer transport. (800 words & fig.)
- 1953** 656 .212 (73)
Railway Age, October 19, p. 68.
Push-button retarders in... new DRGW yard. (2 650 words & fig.)
- 1953** 656 .212 (73)
Railway Age, October 19, p. 78.
New ideas in kirk yard put... electronics at work on E.T. & E. (1 800 words & fig.)
- 1953** 625 .142 .2 (73)
Railway Age, November 2, p. 49.
Ways and means of... making crossties last longer. (2 000 words & fig.)
- 1953** 656 .212 (42)
Railway Age, December 14, p. 100.
Modernisation cuts yard time. (1 000 words & figs.)
- 1953** 625 .214 (73)
Railway Age, December 14, p. 104.
Why hot boxes occur as they do. (1 200 words & figs.)

The Railway Gazette. (London.)

- 1953** 621 .33
The Railway Gazette, August, 7, p. 154.
Electrification through the Pennines - 2. (3 000 words & figs.)
- 1953** 621 .33
The Railway Gazette, August 7, p. 152.
GRANT (J.C.). — Electric traction systems, Present and future. (2 000 words & figs.)
- 1953** 621 .431.72 (72)
The Railway Gazette, August 14, p. 181.
Diesel trains for Mexico. (900 words & figs.)

- 1953 656 .1 (44) & 656 .2 (44)
The Railway Gazette, August 14, p. 183.
Road-rail transport in France. (750 words & figs.)
- 1953 621 .132 .5 (73)
The Railway Gazette, August 21, p. 208; August 28, p. 237.
POULTNEY (E.C.). — Freight locomotive design in America. (3 200 words & figs.)
- 1953 621 .33 (68)
The Railway Gazette, August 21, p. 211.
Cape Western Electrification, South African Railways. (1 250 words & figs.)
- 1953 621 .431 .72 (45)
The Railway Gazette, August 28, p. 234.
Railcar practice in Italy. (1 800 words & figs.)
- 1953 625 .144 .4 (42)
The Railway Gazette, August 28, p. 240.
Ballast cleaning with single-track occupation. (450 words & figs.)
- 1953 656 .212 (42)
The Railway Gazette, August 28, p. 241.
Diesel-operated shunting tractor. (850 words & figs.)
- Diesel Railway Traction. (London.)
- 1953 621 .431 .72 (944)
Diesel Railway Traction, August, p. 169.
Locomotives for New South Wales. (1 900 words & figs.)
- 1953 621 .431 .72
Diesel Railway Traction, August, p. 173.
BOWLER (J.E.). — Speed-sensitive devices for locomotives. (2 000 words & figs.)
- 1953 621 .431 .72 (492)
Diesel Railway Traction, August, p. 175.
Railcars in Holland. (1 450 words & figs.)
- 1953 621 .431 .72 (494)
Diesel Railway Traction, August, p. 178.
Two-power tractors in Switzerland. (550 words & figs.)
- 1953 621 .431 .72 (943)
Diesel Railway Traction, August, p. 186.
Diesel traction in Queensland. (1 600 words & figs.)
- Railway Locomotives and Cars. (New York.)
- 1953 62 (01 (73) & 621 .431 .72 (73)
Railway Locomotives and Cars, September, p. 77.
WILKES (J.F.). — What corrosion inhibitors should and should not do. (4 300 words & figs.)
- 1953 621 .431 .72 (73)
Railway Locomotives and Cars, September, p. 84.
The Santa Fe's Diesel motive power. (5 200 words & figs.)
- 1953 625 .212 (73)
Railway Locomotives and Cars, September, p. 93.
HERMAN (R.H.). — Wheel shops — equipment and operation. (4 800 words & figs.)

In Danish (= 439.81).

Ingeniør ren. (Copenhagen).

- 1953 624 .21 : 624 .19 : 656 (485+489) = 439 .81
Ingeniør ren, No. 14, p. 286.
A bridge-tunnel link through the Öresund. (Summary of the meeting of February 1953, of the Danish Civil Engineers Society in collaboration with the Swedish Technologists Society and the Scandinavian Engineers Club). (6 600 words & fig.)
- 1953 625 .1 : 621 .33 (44) = 439 .81
Ingeniør ren, No. 15, p. 317.
WOLMAR (K.). — Economic advantages of electrified railways. (1 100 words & fig.)
- 1953 621 .431 .72 (489) = 439 .81
Ingeniør ren, No. 29, p. 546.
RISBJERG THOMSEN (E.). — Modern Diesel traction on the DSB. (2 200 words & fig.)

In Spanish.

Boletín de la Asociación permanente del Congreso Panamericano de Ferrocarriles. (Buenos-Aires.)

- 1953 385 (06.1 (7+8)
Boletín de la Asoc. perman. del Congreso Panamericano de Ferrocarriles, julio-septiembre, p. 7-258.
VIII Congreso Panamericano de Ferrocarriles. Washington, D.C. — Atlantic City, N.J. 12-25 de junio de 1953. Delegación de la Comisión Permanente. — Informe. (255 páginas & fig.)
- 1953 625 .143.4 (82)
Boletín de la Asoc. perman. del Congreso Panamericano de Ferrocarriles, diciembre, p. 17 et 37.
La soldadura de rieles en los Ferrocarriles Argentinos. ADAMS (L.). — El progreso verificado en la soldadura de rieles a presión. (3 000 palabras & fig.)

Ferrocarriles y Tranvías. (Madrid.)

- 1953 625 .113
Ferrocarriles y Tranvías, agosto, p. 295.
ALIX ALIX (L.). — La corrección del trazado de curvas y el replanteo de nuevos trazados. (5 000 palabras & fig.)
- 1953 656
Ferrocarriles y Tranvías, septiembre, p. 321.
VIANO (F.G.). — Temas de coordinación de los transportes mecánicos terrestres. (5 000 palabras.)
- 1953 621 .335 (494)
Ferrocarriles y Tranvías, septiembre, p. 331.
HAMACHER HENSE (W.). — Nuevos automotores para servicios especiales de los Ferrocarriles Federales Suizos. (1 500 palabras & fig.)
- 1953 624 .2
Ferrocarriles y Tranvías, octubre, p. 355.
MENDIZABAL (D.). — Auscultación de tramos metálicos. (1 200 palabras & fig.)

1953

625 .144 .2

Ferrocarriles y Tranvías, noviembre, p. 409.

BALBAS REGUER (A.). — *Déclividad transversal y peralte.* (1 200 palabras.)

1953

621 .338 (494)

Ferrocarriles y Tranvías, diciembre, p. 445.

KRAHE (L.). — *Un nuevo tren eléctrico ligero con coche piloto para los Ferrocarriles Federales Suizos.* (1 500 palabras & fig.)

In Italian.

Ingegneria ferroviaria. (Roma.)

1953

621. 33

Ingegneria Ferroviaria, settembre, p. 599.

STAGNI E.). — *Trazione monofase a 50 Hz con motori diretti avviati in corrente continua.* (10 000 parole & fig.)

1953

385 .114 (45) & 656 .2 (45)

Ingegneria Ferroviaria, settembre, p. 611.

RIGGIO (A.). — *Sui costi dei trasporti nella rete delle Ferrovie Italiane dello Stato.* (12 000 parole & fig.)

1953

656 (4)

Ingegneria Ferroviaria, settembre, p. 629.

DE ROSA (G.). — *L'influenza dello sviluppo dei trasporti nel processo di unificazione dell' Europa.* (5 400 parole & fig.)

1953

621 .33

Ingegneria Ferroviaria, settembre, p. 639.

SCAFI (P.) & DI PIETRO (R.). — *Alcune osservazioni relative alle perturbazioni interessanti gli impianti T.E. a c.c. 3 400 V.* (1 600 parole & fig.)

1953

621 .135 .5 (45)

Ingegneria Ferroviaria, ottobre, p. 685.

FASOLI (M.). — *Il nuovo freno per « alta velocità » dei rotabili delle F.S.* (3 000 parole & fig.)

1953

385 .113

Ingegneria Ferroviaria, ottobre, p. 715.

PELLIS (P.). — *I coefficienti virtuali basati sulle spese totali di esercizio nelle ferrovie.* (5 000 parole & tavole.)

1953

656 .257

Ingegneria Ferroviaria, novembre, p. 769.

JACHINO (C.). — *La serratura preventiva nei moderni apparati centrali elettrici.* (1 500 parole & fig.)

1953

625 .26

Ingegneria Ferroviaria, novembre, p. 773.

ORCORTE (A.). — *Esigenze funzionali ed economiche nella programmazione delle attività di manutenzione e riparazione del materiale rotabile.* (6 000 parole & fig.)

1953

621 .33 (45)

Ingegneria Ferroviaria, novembre, p. 784.

PROSPERI (L.). — *I 50 anni di esercizio elettrico delle Valtelline e gli sviluppi della elettrificazione sulla rete F.S.* (4 500 parole & fig.)

Politica dei Trasporti. (Roma.)

1953

625 .162

Politica dei Trasporti, giugno/luglio, p. 274.

CRISCI (F.). — *Il punto di vista economico nella soppressione dei passaggi a livello.* (3 200 parole & fig.)

Trasporti Pubblici (Roma.)

1953

621 .335 (45) & 621 .338 (45)

Trasporti Pubblici, marzo-aprile, p. 247.

Il nuovo elettrotreno E.T.R. 300 delle Ferrovie dello Stato. (1 600 parole & fig.)

1953

625 .42 (45)

Trasporti Pubblici, gennaio-febbraio, p. 7 ; settembre, p. 563; novembre, p. 845.

PERRONE (V.). — *La Ferrovia Metropolitana a Roma (continuazione).* (1 500 parole, fig. & tavole.)

In Netherlands.

De Ingenieur. ('s-Gravenhage.)

1953

625 .2

De Ingenieur, n° 41, 9 October, p. W. 162.

DE PATER (A.D.). — *De vrije zijwaartse trillingen van een stilstaand spoorwegvoertuig op draaistellen.* (3 000 woorden & fig.)

1953

624 (492) & 691 (492)

De Ingenieur, n° 42, 16 October, p. 65.

BOUVY (J.J.B.J.J.). — *De brug in voorgespannen beton over de Drecht te Leimuiden.* (3 500 woorden & fig.)

1953

624 (492) & 691 (492)

De Ingenieur, n° 52, 25 December, p. Bt. 81.

BIEKART (J.H.). — *Het nieuwe viadukt in de Graafseweg te Nijmegen.* (2 500 woorden & fig.)

Spoor- en Tramwegen. (Utrecht.)

1953

385 (492)

Spoor- en Tramwegen, n° 14, 9 Juli, p. 236.

TISSOT VAN PATOT (J.P.B.). — *De economische ontwikkeling der Nederlandse spoorwegen plm. 1928-1953.* (3 000 woorden.)

1953

625 .17 (492)

Spoor- en Tramwegen, n° 14, 9 Juli, p. 257.

DEENIK (J.F.). — *Het mechanisch wegonderhoud bij de N.S.* (1 000 woorden & fig.)

1953

625 .28 (492)

Spoor- en Tramwegen, n° 14, 9 Juli, p. 263.

KOSTER (J.P.). — *Het rollend materieel der N.S. vóór vijf en twintig jaar, nu en morgen.* (1 500 woorden & fig.)

1953

656 .232

Spoor- en Tramwegen, n° 15, 23 Juli, p. 295.

PENTINGA (K.J.). — *Prijsvorming van vervoersdiensten.* (1 700 woorden.)

1953 656 .211 (492)
Spor- en Tramwegen, n° 16, 6 Augustus, p. 311.
SCHELLING (H.G.J.). — Leidens derde stationsge-
bouw. (2 500 woorden & fig.)

1953 625 .232 (44)
Spor- en Tramwegen, n° 16, 6 Augustus, p. 318.
NYMEYER (A.G.). — Rijtuigen van roestvrij staal
voor de S.N.C.F. en de Wagons-Lits. (2 200 woorden
& fig.)

1953 385 (07 (492)
Spor- en Tramwegen, n° 17, 20 Augustus, p. 329.
VOERMAN (Y.) & VAN DER ROEST (G.). — De
instructietrein voor opleiding, omscholing en herin-
structie van machinisten voor de elektrische tractie en
diesel-electrische tractie bij de N.S. (2 500 woorden & fig.)

1953-54 621 .431 .72
Spor- en Tramwegen, n° 17, 20 Augustus, p. 336;
n° 18, 3 September, p. 352; n° 8, 15 April, p. 133.
VAN OMME (N.). — Ontwikkeling van diesel-hydrau-
lische transmissiesystemen. (3 500 woorden & fig.)

1953 656 .212 .5
Spor- en Tramwegen, n° 18, 3 September, p. 345.
PENTINGA (K.J.). — De productiviteit van rangeer-
heuvelds. (1 200 woorden & fig.)

In Portuguese.

Gazeta dos Caminhos de ferro. (Lisboa.)
1954 621 .335 (43)
Gazeta dos Caminhos de ferro, 16 março, p. 12.
LEOWENTRAUT (H.W.). — Nova locomotiva eléc-
trica, tipo «Bo-Bo» dos Caminhos de Ferro Alemães,
série E10, 003 a 005. (2 000 palavras & fig.)

In Swedish (= 439.71).

Järnvägs-Teknik. (Statsbaneingenjören)
(Stockholm.)
1953 621 .33 (43+485) = 439 .71
Järnvägs-Teknik (Statsbaneingenjören), n° 2, p. 32.
EDENIUS (R.). — Financial comparison between the
German and Swedish systems of operation of electrified
railway lines. (1 200 words & fig.)

Meddelanden från Svenska Lokaltrafikföreningen. (Stockholm.)

1953 656 .25: 625 .42 (485) = 439 .71
Meddelanden från Svenska Lokaltrafikföreningen, n° 2,
p. 39.
BOBERG (I.). — Signalling system on the Stockholm
Underground Railway. (8 800 words & fig.)

Nordisk Järnbanetidskrift. (Stockholm.)

1953 656 .254 (73: 489) = 439 .81
Nordisk Järnbanetidskrift, n° 2-5.
Danish engineers visit railways in U.S.A. (Economic
Cooperation Administration (ECA) special mission).
Summary: *Part A: General* (No. 2). *Part B: Electrified
railways* (No. 3). *Part C: Passenger rolling stock* (No. 4).
Part D: Telecommunications (No. 5). (7 900 words & fig.)

1953 625 .144 .4 (480) & 625 .173 (480) = 439 .71
Nordisk Järnbanetidskrift, N° 7, p. 147.

VILUKSELA (M.). — Experiences of the use of modern
machines in railway works and railway construction.
(2 900 words & fig.)

ANKER JENSEN (H.). — Danish report. (700 words
& figs.)

STRÖMO (O.). — Norwegian report. (800 words
& figs.)

HEDBÄCK (T.). — Swedish report. (800 words
& figs.)

1953 656 .222 .1: 625 .113 (485) = 439 .71
Nordisk Järnbanetidskrift, n° 7, p. 164.

GUDMUNDSSON (N.). — Relation between maxima
speeds permitted and the radii of curves. (2 000 words
& fig.)

JESSEN (M.). — Danish report. (1 000 words.)

ROUNU (L.). — Finnish report. (900 words & figs.)

SKJENNEBERG (K.). — Norwegian report (600
words.)



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